

PARTICULATE MATTER EMISSION AT SELECTED
CONSTRUCTION AREA IN KUANTAN

BY

PUTRI SHAZLIA BINTI ROSMAN

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ABSTRACT

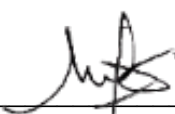
The release of particulate matter from the construction area is undeniable. The spread of PM_{2.5} and PM₁₀ also occurs with the presence of wind velocity and wind direction blowing through the study area, Priya construction site in Kuantan, Pahang Darul Makmur. It is not trivial to state that PM_{2.5} and PM₁₀ emissions have received less attention from the Construction Industry Development Board (CIDB) the agency that regulates, facilitates and develops the construction industry in Malaysia. Therefore, this research aims to investigate the dispersion of PM_{2.5} and PM₁₀ using the Rstudio software and WRPLOT Software, in analysing and plotting wind rose using the meteorological data. Rstudio, a state-of-the-art technology software tool helps determine the dispersion of PM_{2.5} and PM₁₀ that is emitted from the activities at the construction site. Thus, the particulate matter was monitored daily for the 6 months from June to November 2020 using an Aeroqual's series 500, a portable air quality monitor, to collect data at the construction at Priya Construction site, Penor, Pahang. Two different data, particulate matter concentration and meteorology data (Malaysian Meteorological Department) were analysed together in Rstudio to map the PM_{2.5} pattern distribution. The meteorology data were analysed under the WRPLOT software, automating the process of calculating wind direction and frequency, and produced other information such as wind rose pattern, frequency distribution and wind rose graph. Rstudio, an integrated development environment, analyzed the PM_{2.5} concentration together with meteorological data in openair package, in constructing the coding instruction using the core function and mandatory variables. The WRPLOT result was found that the total of 15% wind was blown from the south, 9% wind blown from south-southwest, 8% wind blown from north and 39.96% wind blown from other directions. Most of the wind speed are presented at the construction site were between 0.5 to 2.10 m/s and between 2.10 to 3.60 m/s. The Rstudio was interpreted that 24% of PM_{2.5} dispersed from the South-southwest with 14%, most the frequency of count by wind direction 5 to 10 µg/m³, 18% of PM_{2.5} dispersed from the East, with 8%, most the frequency of count by wind direction 0 to 5 µg/m³, 13% of PM_{2.5} dispersed from two different wind direction, North-northeast and Southwest, where 6% and 4% most the frequency of count by wind direction, with 0 to 5 µg/m³ and 5 to 10 µg/m³ respectively. On top of that, the bivariate polar showed that about 0 to 8 µg/m³ of PM_{2.5} distributed to the North (N), Northwest (NW), Southwest (SE), and Northeast (NE) areas in the range of 4 m/s to 18 m/s within 6 months from June to November 2020. The spread of PM_{2.5} occurs with the presence of wind where the time of the presence of this wind is difficult to predict and it cannot be controlled. Activities in the construction area is a very significant source of PM emissions and it should be regulated by emphasizing stricter regulations in the construction area. However, if viewed from a legal point of view, the continuous monitoring of PM_{2.5} and PM₁₀ is not placed in any legal act or guidelines under government agencies such as CIDB, DOE, JKR or local authority. Finally, the use of Rstudio as a statistical computing is able to provide the results of the spread of PM with a clearer visual and the environmental impact can be controlled by controlling the activities that occur in the construction area.

ملخص البحث

إن انبعاث الجسيمات الدقيقة أو ما تعرف بالهباء الجوي من مناطق البناء أمر لا يمكن إنكاره، حيث يحدث انتشار للجسيمات الدقيقة ذات الأقطار المختلفة أمثال $PM_{2.5}$ و PM_{10} بسبب سرعة الرياح واتجاهها. لا يمكن القول أيضاً بأن تلك الانبعاثات لم تحظ بالاهتمام الكافي من مجلس تطوير صناعة البناء (CIDB)، الهيئة التي تنظم وتسهّل وتطور صناعة البناء في ماليزيا. لذلك، هدف هذا البحث إلى التحقيق في انتشار $PM_{2.5}$ و PM_{10} باستخدام برنامجي Rstudio و WRPLOT، في تحليل ورسم وردة الرياح (أو قرص البوصلة) باستخدام البيانات المناخية. يساعد برنامج RStudio في تحديد انتشار $PM_{2.5}$ و PM_{10} المنبعث من الأنشطة في مواقع البناء. تم مراقبة الجسيمات الدقيقة يومياً لمدة 6 أشهر، ابتداءً من يونيو حتى نوفمبر 2020 باستخدام جهاز مراقبة جودة الهواء المحمول من سلسلة Aeroqual 500، لجمع البيانات في موقع البناء في بريا (Priya)، بنور (Penor)، ولاية باهانغ بماليزيا. تم تحليل نوعين مختلفين من البيانات، تركيز الجسيمات الدقيقة وبيانات الأرصاد الجوية (دائرة الأرصاد الجوية الماليزية) معاً في Rstudio لرسم نمط توزيع الـ $PM_{2.5}$. تم تحليل بيانات الأرصاد الجوية باستخدام برنامج WRPLOT، مما أتاح أتمتة عملية حساب اتجاه الرياح وتكرارها، وأنتج معلومات أخرى مثل نمط وردة الرياح، وتوزيع التكرار، ورسم وردة الرياح. كما قام Rstudio بتحليل تركيز $PM_{2.5}$ مع بيانات الأرصاد الجوية في حزمة openair، لبناء ترميزات البرمجة باستخدام الوظيفة الجوهرية والمتغيرات الإلزامية. توصلت نتائج WRPLOT إلى أن 15% من الرياح تهب من الجنوب، و9% من الجنوب والجنوب الغربي، و8% من الشمال، و39.96% من اتجاهات أخرى. كانت معظم سرعات الرياح في موقع البناء تتراوح بين 0.5 إلى 2.10 م/ث و بين 2.10 إلى 3.60 م/ث. وقد حلل Rstudio أن 24% من $PM_{2.5}$ انتشرت من الجنوب إلى الجنوب الغربي بنسبة 14%، وكانت معظم تكرارات العد حسب اتجاه الرياح تتراوح بين 5 إلى 10 ميكروغرام/م³، و18% من $PM_{2.5}$ انتشرت من الشرق، وكانت معظم تكرارات العد حسب اتجاه الرياح تتراوح بين 0 إلى 5 ميكروغرام/م³، و13% من $PM_{2.5}$ انتشرت من اتجاهين مختلفين للرياح، الشمال إلى الشمال الشرقي بنسبة 6% وبتكريزات 0 إلى 5 ميكروغرام/م³ والجنوب الغربي بنسبة 4% وبتكريزات 5 إلى 10 ميكروغرام/م³. علاوة على ذلك، أظهرت بيانات الاستقطاب ثنائي المتغير أن حوالي 0 إلى 8 ميكروغرام/م³ من $PM_{2.5}$ تم توزيعها إلى الشمال، الشمال الغربي، الجنوب الغربي، والشمال الشرقي في نطاق من 4 م/ث إلى 18 م/ث خلال 6 أشهر من يونيو إلى نوفمبر 2020، ويحدث انتشار للـ $PM_{2.5}$ بوجود الرياح. إن الأنشطة في منطقة البناء تعتبر مصدراً رئيسياً لانبعاثات الجسيمات الدقيقة ويجب تقليلها من خلال التأكيد على لوائح أكثر صرامة في منطقة البناء. وإذا نظرنا من منظور قانوني، فإن المراقبة المستمرة لـ $PM_{2.5}$ و PM_{10} ليست موجودة في أي قانون أو في إرشادات الهيئات الحكومية مثل CIDB، DOE، JKR أو السلطات المحلية. أخيراً، استخدم Rstudio كأداة حسابية إحصائية قادر على تقديم نتائج انتشار الـ $PM_{2.5}$ بصورة أوضح، ويمكن التحكم في الأثر البيئي من خلال التحكم في الأنشطة التي تحدث في منطقة البناء.

APPROVAL PAGE

The thesis of Putri Shazlia Binti Rosman has been approved by the following:



Mohd Armi Bin Abu Samah
Supervisor

Mohd Ramzi Bin Mohd Hussain
Co-supervisor

Shamzani Affendy Bin Mohd Din
Internal Examiner

Mohd Khairul Amri Bin Kamarudin
External Examiner

Kamaruzzaman Bin Yunus
Chairman

DECLARATION

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

Putri Shazlia Binti Rosman

Signature.....

Date : 23/1/2025



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LIST OF SYMBOLS

C	Celsius
CO	Carbon Monoxide
E	East
ENE	East Northeast
ESE	East Southeast
N	North
NE	North East
NEP	National Policy on the Environment
NNE	North Northeast
NNW	North Northwest
NO ₂	Nitrogen Dioxide
NW	North West
SO ₂	Sulphur Dioxide
S	South
SE	South East
SSE	South Southeast
SSW	South Southwest
SW	South West
W	West
WNW	West Northwest
WSW	West Southwest
O ₃	Ground Level Ozone
PM _{2.5}	Particulate matter with aerodynamic diameter below than 2.5 microns
PM ₁₀	Particulate matter with aerodynamic diameter below than 10 microns
RH	Relative Humidity
µg/m ³	Microgram per cubic meter
m/s	Meter per second
mm	Millimetre
1 hour	Hourly average concentration
8 hour	8 hour average concentration
24 hour	24 hour average concentration

LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
API	Air Pollution Index
APIMS	Air Pollution Index Management System
CAQM	Continuous Air Quality Monitoring
COVID-19	Infectious disease caused by the SARS-CoV-2 virus
CIDB	Construction Industry Development Board
DOE	Department of Environment
DOSM	Department of Statistics Malaysia
EIA	Environmental Impact Assessment
EQA	Environmental Quality Act
EQRPM	Environmental Quality Report
GPS	Global Positional System
GHO	Global Health Observatory
IQAir	World Air Quality Report
JKR	Jabatan Kerja Raya
JUPEM	Department of Survey and Mapping Malaysia
MAAQs	Malaysian Ambient Air Quality Standard
MAQM	Manual Air Quality Monitoring
MBK	Majlis Bandaraya Kuantan
MCO	Malaysian Movement Control Order
METMalaysia	Malaysian Meteorological Department
NAAQS	National Ambient Air Quality Standard
PM	Particulate Matter
RKKSHK	Rumah Kanak-kanak Sultanah Hajjah Kalsom
RMCO	Recovery Movement Control Order
RMG	Recommended Malaysian Air Quality Guidelines
UMPSA	Universiti Malaysia Pahang Al-Sultan Abdullah
UTM	Universiti Teknologi Malaysia
US AQI	United States Air Quality Index
US-EPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Kuantan is the capital city of Pahang where the total population of Kuantan District is recorded a total of 443,796 people. Kuala Kuantan is an urban area population, and it is a rapidly, developing area with a concentration of 76.11% of the district population. (RTD, 2018). Kuantan was proclaimed as a city on 21 February 2021, where many economic developments such as the East Coast Rail Link, as well as telecommunications and road infrastructure meet the needs and increase of population in suburbs and nearby towns. Due to that, the air pollution from the construction site in Kuantan areas needs to be monitored for its emission dispersion to meet with criteria of Kuantan Sustainable City. Recently, Kuantan was recognized as one of the Happiest Cities in 2022 in Malaysia in conjunction with the World Happiness Day which falls on March 20 every year (Boy Kamal, 2023). Therefore, the Kuantan City Council has planned to increase the development in Kuantan District through detailed planning stated in Rancangan Tempatan Daerah Kuantan 2035 (Penggantian). Many developments in residential areas and commercial buildings will be developed by the Kuantan City Council to meet the demand. However, simultaneous, and uncontrolled development will affect air quality and at the same time will disturb the health of residents. One of the air pollution emissions from the construction area is particulate matter.

Particulate matter is potable and suspended in the air and it is present in different chemical, and physical characteristics and its sources of produce. Particulate matter is known as a complex mixture of solid and liquid droplets found in the air such as soil, dust, soot, metals, smoke, dirt, or something that you can see through your naked eye. The size of the particulate matter is ranging from 0 to 100 μm (USEPA, 2023). The particulate size is divided into fine particles and coarse particles. The fine particles with an aerodynamic diameter of less than 2.5 micrometers known as $\text{PM}_{2.5}$ are commonly available in the city air such as smoke or haze are mainly constituted of carbon and also

a variety of metals such as cadmium, vanadium, mercury, lead and chromium that found in the urban aerosol. The coarse particles with aerodynamic diameter generally larger than $2.5\text{ }\mu\text{m}$ and smaller than or equal to $10\text{ }\mu\text{m}$, known as PM_{10} , constitute form man-made processes such as road dust, forest fire, land clearing fires, construction and demolition, soil erosion and industrial processes, mining and agriculture burning causing miscellaneous coarse particles emitted into the atmosphere. Four main stages of building construction such as main structure, decoration stage, foundation, and earthwork generate large quantities of particulate matter in several different aerodynamic equivalent diameters (Araujo et al. 2014).

The release of particulate matter comes from the 2 primary stages of the construction project. The first stage is the construction phase. During this phase, $\text{PM}_{2.5}$ is generated during the earthwork and foundation stages (Fan et al, 2020). Many particles such as dust are emitted into the atmosphere from activities such as moving heavy vehicles from or within the construction area. The more the moving of vehicles, the more the particles emit. Excavation activities by moving rocks, tree roots and soil out of certain areas for preparation for underground basement. Excavators move the rocks, topsoil, mock and soil by lift and claws that produce dust. Other than that, the excavating activities in the purpose of such as cutting and filling where cross-sections of existing for leveling the land involve removing or cutting off undesired land to elevate desired height and filling the lower level. These techniques create dust emissions from soil removal.

The second stage is post construction where post-construction is a period that occurs after the physical construction ends until the project is turned over to the owner. During this state, activities such as cleaning all equipment, demobilizing the labor to the new project construction site, and uninstalling the temporary house, post guard, office and sanitaryware cause dust to emit to the atmosphere. The movement of heavy vehicles contribute the pollution.

The particulate matter remains in the air and it may be suspended by the wind on land surfaces and oceans for a long period. particulate matter is also suspended in the air because of its thermal conditions, density, and size (Yang et al., 2018). However, the composition, health effect, dosimetry, and sources diverge between each fine and

coarse particle. Exposure to particulate matter for a long time would affect human health and also lead to environmental damage and material damage that will involve millions or maybe billions of cost to restorative and rehabilitate of the damage done by the particulate matter. The size of particulate matter will define different types of exposure who exposed to it. For example, particulate is more than $10\mu\text{m}$, and when we breathe it in, it penetrates the lungs and leads to health impacts from coughing to asthma attack and severe difficulties such as heart attack, premature death, high blood pressure and heart attack. Exposure to particulate matter less than 2.5 in diameter, can cause lung inflammation and tissue damage when it travels deep into the lung through the respiratory tract. Exposure for a long period may lead to permanent respiratory problems such as asthma, heart disease, and chronic bronchitis and lead to premature death. The impact of particulate matter on the environment would cause smog and visibility reduction due to the formation of $\text{PM}_{2.5}$ in the atmosphere that alters the light in form of scattering and absorption. The deposition of airborne particles into the ocean will affect the quality of water bodies, turn acidic water conditions in streams and lakes, damage farm crops such as tropical fruits, coconut, flowers and vegetables, and if particles contain a metal compound, it will reduce yield and plant growth when it deposits on the plant and soil. Other than that, the acidity that is present in particles in the rainwater potentially corrodes metal and deteriorates stone and paint quickly.

Haze also contributes to the availability of $\text{PM}_{2.5}$ in the atmosphere. Danial (2013) reported that several parts of Malaysia experience haze with unhealthy levels of air quality due to fires in Indonesia where nearly every dry season, fires from clear land activities in pulp and paper and palm oil plantations have triggered the risks to public health and airlines routing system.

Air pollution is a major threat to global and local health. The emissions of $\text{PM}_{2.5}$ affect Malaysian citizens where according to the State Global Air 2020 Report, death increased by 30% in the last 10 years (CREA, 2022). The effect of air quality may have a serious impact on health, especially in the residential area neighboring an industrial park that produces dust or fumes through its process of materials or activity. Other than that, construction dust can have serious effects on workers, and if it is exposed for a long period, it will eventually kill them. The dust produced from construction sites may be classified into three main types such as silica dust (concrete, mortar), wood dust

(hardwood, softwood), and lower toxicity dust (limestone, gypsum, and marble). There are three basic respiratory effects, respirable, thoracic and inhalable (inspirable).



Figure 0.1 Haze in Kuala Lumpur dated October 2023 (Danial, 2023)

The respirable dust particles are under 25 microns in diameter, the thoracic dust particles are under 25 microns and inhalable dust particles are under 100 microns in diameter (Luis, 2022). Figure 1.2 shows the respiratory system impact if exposed to dust. Dust Inhalable and dust respirable have two different side effects, dust inhalation may cause health effects such as lung disease, shortness of breath, cancer, fibrosis, and more. While dust is respirable, cannot be seen by physical effect and can't be seen by the naked eyes (Aeroqual, 2023). According to Mohamed 2018, natural mineral found in clay, gravel and sand contains Crystalline silica that is widely used in construction that can cause severe pulmonary disease due to their granulometry.

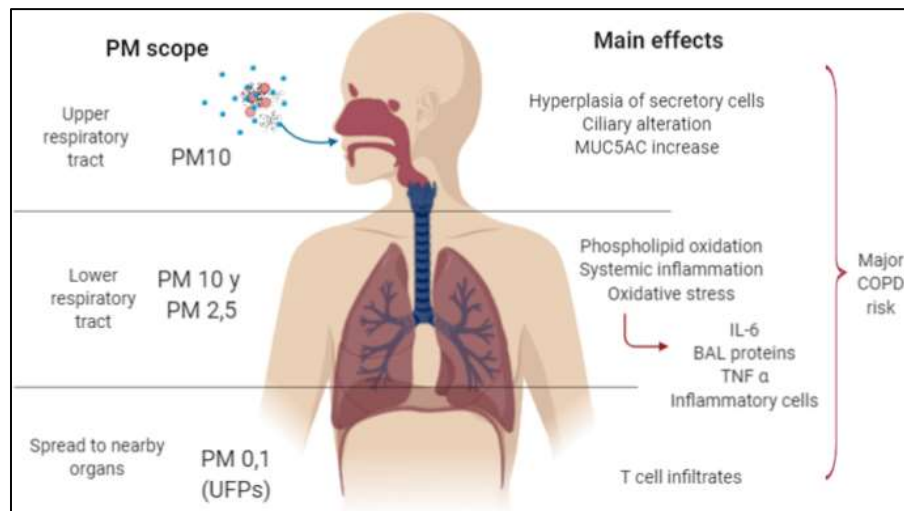


Figure 0.2 The respiratory system impact if exposed to dust or fumes.
(Loaiza et al., 2022)

Construction is anything that is being built on either a small or big scale. The type of construction comes in many forms from the house built to the commercial, industrial, and infrastructure including bridges, roads, power supplies, mass transit, telecommunication, etc. In a big-scale area involving more than 400 hectares, most developers plan to shape the area with the purpose either of creating a new township or industrial park for future development. In June 2020, inspected by the Construction Industry Development Board (CIDB), Malaysia experienced dwindling progress in industrial construction as 5,000 construction sites from 6750 construction were not operating due to the threat of the COVID-19 pandemic. However, in December 2021, the industry sector increasingly recovered from the downturn with the support of the government plan to improve tourism infrastructure, transport network, demand for housing, and renewable energy projects.

The digital transformation of the construction industry nowadays enhances the delivery capability and capacity of staff and various collaborative projects. Technology in a building structure is changing from traditional construction techniques to high technology with an assessment of building information modeling (BIM) software helps to plan, design, construct, operate well as maintain the building and various physical utilities such as tunnels, port, water, refuse, electricity, communication utility road, and gas. Along with that, starting in the year 2008, Malaysia applied precast concrete framed buildings with supporting guideline documents developed by the IBS (Industrialized

Building System) Standard Committee with the assistance of the Construction Industry Development Board Malaysia (CIDB) and Universiti Teknologi Malaysia (UTM). The precast components (framed buildings) such as walls, slabs, staircases, columns, and beams are fabricated or manufactured off-site from the construction site. The fabricated precast component is then delivered to the site for erection and assemblage to build a complete structure. The benefit of these precast construction reduces air pollution, noise, and debris.

The emission of PM_{2.5} from the construction, however, still happens when the technology is introduced. Dust and smoke from the movement of tracks, site vehicles, and from clearing land activity led to air pollution emitted from the construction site. The emission continuously exists although mitigation action is already taken in place. We could only minimize the emission, but we can stop the emission from happening. This research is carried out in Kuantan which is under the jurisdiction of the Majlis Bandaraya Kuantan (MBK). The research was preferred due to many construction projects such as housing and commercial buildings being constructed in the jurisdiction of this city. However, legal references and guidelines for PM_{2.5} monitoring in construction areas are not held since PM_{2.5} is not held in any law, regulation or guidelines.

1.2 BACKGROUND OF THE STUDY

The construction industry is an economic investment that significantly contributes to national economic development and generates income for the country (Khan et al., 2014). The construction sector recorded the value of construction work down to RM34.5 billion in the Third Quarter of 2017. However, in 2015 the construction sector recorded growth performance with a gross output of RM177.9 billion which increase of about RM86.6 billion as compared to 2010 with a compound annual growth rate of 14.3 percent (DOSM, 2017). Despite this, to achieve high income for the nation, pollution especially particulate matter from construction needs to be tackled and mitigation measures need to be implemented for safety and better health.

Air pollution from construction sites is also one of the contributors to atmospheric pollution due to the emission of particulate matter, which creates health problems and environmental problems. Approximately about 0.8 million premature deaths and 6.4 million years of life are lost annually due to air pollution caused by PM_{2.5} in the atmosphere (Cohen et al., 2005). Research done by Alexeeff (2023) reveals that PM_{2.5} exposure at moderate concentrations could cause an increased risk of incident myocardial infarction (AMI), ischemic heart disease (IHD) mortality, and cardiovascular disease (CVD) mortality. The investigation revealed by Garcia *et al.* (2023) that the effects of PM_{2.5} are strongly associated with the pathological genesis where the toxicological potential is linked to inflammation generation pathways, which may comprise genes that are involved in inflammation processes. During the construction, particulate matter (PM) will be emitted from several sources of activities that occurred at the construction site. The source of PM emission can be identified from off-site vehicles and on-site machinery. Other than that, the movement of construction vehicles such as bulldozers, excavators, or dump trucks also produces particulate matter from the movement action or during the routine work at the site.

In certain neighbourhoods, air pollution is a nuisance and may become a major arguing issue that may lead to a court case. According to Marquette's law review on Josh vs. Dairyland Power Cooperation Josh (1969), brought by three farmers had claimed damage to their crops and land due to the emission of Sulphur gases into the atmosphere. The power company plant was found guilty of continuing nuisance and causing injury and damage to the plaintiffs. Air pollution is not a candy issue, but it can become a major issue when involving national awareness.

However, particulate or dust pollution is not new to us as it has been happening for many years. Many codes and regulations on air quality are constructed but still, the public must bear the nuisance for a temporary period during construction operations. Therefore, mitigation measures must be implemented to reduce the short-term impact on the public and to minimize damage to the environment. Planning is important before the move and clearing up the land as it depends on the purpose of the land, size, and location. The norm practical applied by the contractor in a land clearing is a pushover, grind and burning.

The issues of environment pollution is the most important issue for Malaysians. Issues on dust and particles matter in the news become more apparent as people now start to be aware of the hazards that cause serious health effects to them. Many of them start to send a letter to the government agency or to non-government bodies to seek help with the problems that they suffer. The local newspapers such as Berita Harian, The Star, Utusan Malaysia etc. become a medium of compliance for them to release stress and seek solutions from agencies. The local TV news such as Berita TV3 also aired the environmental issues and complaints from the suffering residents. Below are some issues examples due to dust and particulate matter in the local newspaper and local TV news on air about the problem. However, nowadays many platforms, such as TikTok, Facebook, and Instagram, are people's choices to spread information about environmental pollution that is happening around them.

Table 0.1 Several Malaysia local news on dust emissions and other environmental problems.

Title of Issues	Environmental Problem related	Sources of News
Construction dust has them fuming	dust, noise	9 Dec 2006, The Star
Jalan berdebu ganggu penduduk	Dust, noise, vibration	8 Mac 2019, BH online
Projek pembinaan punca debu dan habuk	Dust, land erosion	6 September 2020, Buletin TV3
Setiap hari sedut habuk binaa	Dust, traffic congestion, noise	30 May 2017, Berita Harian
Kecewa aduan tak dilayan	Dust, noise	20 Feb 2017, Berita Harian
Projekancam keselamatan	Dust, noise	26 July 2018, Utusan Malaysia,
Construction irks residents	Dust, noise	26 September 2014, NST

The Star reporting on “Construction dust has them fuming” were the residents of Air Panas, Setapak having a breathing problem due to dust emitted from the construction of the Duke Highway (Duta-Ulu Kelang Highway) by Ekovest Bhd. The residents experience sticky eyes and sore throats all the time. The noise from the construction site also causes nuisance since the operation hour of the construction site is from 8 am to 10 pm daily.

Figure 1.3 showed the BH Online reporting by reporter Samadi Ahmad on 8 Mac 2019, title “Jalan berdebu ganggu penduduk”. The resident of Jalan Bukit Perah 2, Kampung Olak Lempit experienced the dust from the vehicle construction movement from the Lebuhraya Persisiran Pantai Barat (LPPB) Highway. The vehicle movement caused dust emissions and created an unsafe environment such as vibration and noise in 1000 residents’ area. The residents already experienced 1 year due to this project being started in the year 2014 consisting of 233 kilometer highway construction.



Figure 0.3 Article ‘Jalan berdebu ganggu penduduk’ reported by Berita Harian, 8 Mac 2019.

Figure 1.4 showed the issue on “Projek Pembinaan Punca Debu dan Habuk” was aired by Buletin TV3, on 6 September 2020 reported that about 500 people from 150-unit houses at Taman Bandar Baru Sungai Udang, Melaka experience dust from the school project construction beside their residential area. The school project construction was entitled under Alor Gajah Municipal Council and the effect residents are under the jurisdiction of Majlis Bandaraya Melaka Bersejarah (MBMB). The project had caused dust to their property, especially on clothes and their windows and also land erosion happens inside their storm drain in the residential area. The project proponent had already received a notice from the local authority to stop work for 14 days on 4 September 2020. Three other notices have been issued to the project proponent upon these issues on 25th January 2018, 21st January 2019 and 19th April 2019.



Figure 0.4 News title of ‘Projek Pembinaan Punca Debu Dan Habuk’ on TV3, 6 September 2020

Berita Harian with the title of “Setiap Hari Sedut Habuk Binaan” dated 30 May 2017, reported by Aliff Ashraf Fadzillah, about the residents of Kampung Batu Muda Tambahan, Kuala Lumpur have experience dust from construction waste emitted from nearby strata development project construction. The dust problem causes their property,

especially their homes and cars. Other issues appear are the traffic congestion at the entrance road to the residential area due to the movement of the heavy trucks from the construction site and noise issues at night.

News from Berita Harian dated 20th February 2017 by reporter Norhaslinda Abd Wahid, about the dust and noise pollution from the reclamation project near the Baystar condominium, Bayan Lepas, Pulau Pinang. The reclamation project consists of an area of 10 hectares near the Pulau Jerejak, where several new condominiums will be built on the reclamation site. The Baystar resident experiences 24 hours of dust and noise problems from reclamation site construction. Some children and old folk from Baystar residential also had coughing and cold when exposed to dust from reclamation site construction. Noise pollution also fears them as the noise continues to haunt them every day.

Utusan Malaysia dated on 26 July 2018, reported by Zulfadli Sharifudin, the residents of Vista Angkasa Apartment had to experience dust and noise problems from nearby condominium project development at Jalan Kerinchi, Kuala Lumpur. The condominium project construction site was just 50 meters away from Vista Angkasa Apartment and the project was started a year ago. The residents have to suffer the dust as it is near to their residential area. Traffic congestion also becomes a problem for them as the residential main road is used as a construction road also.

In the New Strait Times, dated 26th September 2014, about 50 residents of Taman Bukit Mewah, Tampoi are experiencing dust and noise pollution caused near the construction of Kemayan City. The construction project involves the construction of a four-star hotel, a service apartment, and a 10-level shopping mall. The dust from the construction site flew into their homes and the deposit of clothes and cars. Some residents, especially toddlers and the elderly, are suffering from lung infections and other health issues. Some residents have been frustrated with the environmental problem and urged the developer to come up with solutions and hope the project will end soon.

Many more issues with dust have been experienced by our Malaysians due to construction site activity. Some issues are taken up by the local authority and by the

government bodies. The developer needs to think about the safety and the environmental impact of their project during the pre-planning stage. The pre-planning stage will help the developer develop mitigation measures and define pollution sources that may be emitted from their project. These may be a benefit to the developer in cost management, reducing delay time progress and reducing the number of complaints from residential areas. The issue of air pollution from construction areas is often underestimated or not given a serious impact by developers to the residents of the surrounding area. However, the detrimental effects of dust, emissions, and noise can significantly affect the health and well-being of those living nearby. It is crucial for developers to implement stricter measures to mitigate these impacts and ensure a healthier environment for the community.

Every country faces the same air pollution problem and it's become worse. Air pollution appears when particulate, dust, odour, or fumes are present in the atmosphere and change either in chemical composition or physical appearance. According to the International Standardization Organization (ISO 4225:1994), the definition of dust is small particles in the form of a solid which less than 75 μ m in diameter. PM_{2.5} is very fine and dangerous when exposed for a long-time exposure. The size of PM_{2.5} is 2.5 microns. The continuous exposure to PM_{2.5} will cause effects on the human respiratory system. It will cause an acute effect and a chronic effect. Acute effects are exposure to high concentrations of PM_{2.5} can irritate the airways, causing symptoms like coughing, shortness of breath, wheezing, and a sore throat. While chronic effects are that long-term exposure can lead to persistent inflammation in the airways, which increases the risk of chronic respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD).

Premature mortality, cardiovascular disease and respiratory illness are some of the health effects linked directly to exposure to PM_{2.5}. However, World Health Organization's (2013) guidelines state that the air quality in Malaysia is considered moderate unsafe as the annual mean concentration of PM_{2.5} is 15.6 μ g/m³ which exceeds 10 μ g/m³ of recommended maximum by WHO. World Air Quality Report 2020 done by +IQAir has compiled an air quality report from all over the world by collecting ground-level monitoring stations. This report proves that 600,000 deaths most of them are children and about 7 million cases of premature death annually. Table 1.1 below is

the several world rankings of PM_{2.5} concentration (µg/m³) weighted by population reporting in 2020. The country that is involved in this world ranking report is the country that has ground-level air monitoring and the country that is willing to provide air quality data to the +IQAir organizer.

The report uses the US Air Quality Index (AQI) as the WHO target in visualizing the PM_{2.5} level. The US Air Quality Index is a daily pollutant that is divided into 6 categories and this index is designed for short-term (24-hour) PM_{2.5} exposure to communicate the hazards. The green is labeled as “Good” while the purple is labeled as “Hazardous”. Hazardous is very dangerous and the public will experience adverse health effects and strong irritations. Malaysia, like many other countries, faces significant challenges with air quality, particularly from PM_{2.5} levels associated with industrial emissions, peat fires, vehicle exhaust, monsoon events, and haze events. Adopting the US AQI as a standard for monitoring air quality and using the WHO guidelines as targets could have several key benefits for the country such as Malaysia can more effectively monitor and communicate air quality levels to the public, particularly vulnerable groups like children, the elderly, and people with existing respiratory or cardiovascular conditions. It can also serve as a benchmark to reduce pollution to a minimal level of health risk with WHO guidelines for PM_{2.5} (annual average of ≤ 10 µg/m³ and 24-hour average of ≤ 25 µg/m³).

Table 1.2 shows the US AQI level of PM_{2.5} reported in the +IQAir report 2023. The ranking report stated that Bangladesh is the highest annual mean PM_{2.5} concentration in the world ranking at 77.1 µg/m³ (unhealthy), followed by Pakistan with 59 µg/m³ (unhealthy) and the third highest in India with 51.9 µg/m³ (unhealthy for sensitive groups). While for the world’s capital city ranking with PM_{2.5} concentration, the highest city is Delhi, India with 84.1 µg/m³ (unhealthy), followed by Dhaka, India with 84.1 µg/m³ (unhealthy) and the third city is Ulaanbaatar, Mongolia with 46.6 µg/m³ (unhealthy for sensitive groups). In India, the country practices the open burning of crops as the best solution approach to their people. This practice is affordable and very quick in the transition from summer rice crop to winter wheat crop. Other contributing sources to air pollution in India are construction, biomass for cooking, electricity generation, waste burning and transportation.

Table 0.2 World Country / Regional Ranking average PM_{2.5} concentration Note.
The data collected from ground-level monitoring stations
around the world. (+IQAir Report, 2023).

No	Country			Country		No	Country	
1	Bangladesh	77.1	35	Croatia	21.4	69	Philippines	12.8
2	Pakistan	59.0	36	Cambodia	21.1	70	Malta	11.8
3	India	51.9	37	Georgia	20.4	71	Singapore	11.7
4	Mongolia	46.6	38	Algeria	20.2	72	Lithuania	11.3
5	Afghanistan	46.5	39	Madagascar	20.0	73	Latvia	11.2
6	Oman	44.4	40	Kosovo	20.0	74	Senegal	11.1
7	Qatar	44.3	41	South Korea	19.5	75	France	10.9
8	Kyrgyzstan	43.5	42	Chile	19.3	76	Austria	10.5
9	Indonesia	40.7	43	Ukraine	19.2	77	Curacao	10.4
10	Bosnia Herzegovina	40.6	44	Guatemala	19.2	78	Spain	10.2
11	Bahrain	39.7	45	Mexico	18.9	79	Germany	9.8
12	Nepal	39.2	46	Turkey	18.7	80	Japan	9.7
13	Mali	37.9	47	Italy	18.5	81	Netherlands	9.6
14	China	34.7	48	Greece	18.4	82	USA	9.4
15	Kuwait	34.0	49	South Africa	18.0	83	Denmark	9.4
16	Tajikistan	30.9	50	Peru	17.9	84	Russia	9.1
17	North Macedonia	30.6	51	Macao SAR	17.8	85	Portugal	9.0
18	Uzbekistan	29.9	52	Turkmenistan	17.0	86	Luxembourg	9.0
19	Myanmar	29.4	53	Poland	16.9	87	Switzerland	8.9
20	UAE	29.2	54	Israel	16.9	88	Belgium	8.6
21	Vietnam	28.1	55	Albania	16.0	89	Ireland	8.4
22	Bulgaria	27.5	56	Cyprus	15.8	90	United Kingdom	8.2
23	Iran	27.2	57	Romania	15.8	91	Costa Rica	7.6
24	Ghana	26.9	58	Malaysia	15.6	92	Ecuador	7.6
25	Montenegro	26.1	59	Colombia	15.6	93	Australia	7.4
26	Uganda	26.1	60	Hongkong	15.4	94	Andorra	7.3
27	Armenia	24.9	61	Slovakia	15.3	95	Canada	7.2
28	Serbia	24.3	62	Taiwan	15.0	96	Iceland	7.0
29	Saudi Arabia	23.3	63	Jordan	14.9	97	New Zealand	5.9
30	Sri Lanka	22.4	64	Ethiopia	14.7	98	Estonia	5.8
31	Laos	22.4	65	Hungary	14.3	99	Norway	5.0
32	Ivory Coast	21.9	66	Argentina	14.2	100	Finland	5.0
33	Kazakhstan	21.9	67	Kenya	14.2	101	Sweden	3.7
34	Thailand	21.4	68	Angola	13.0	102	Virgin Islands	3.7

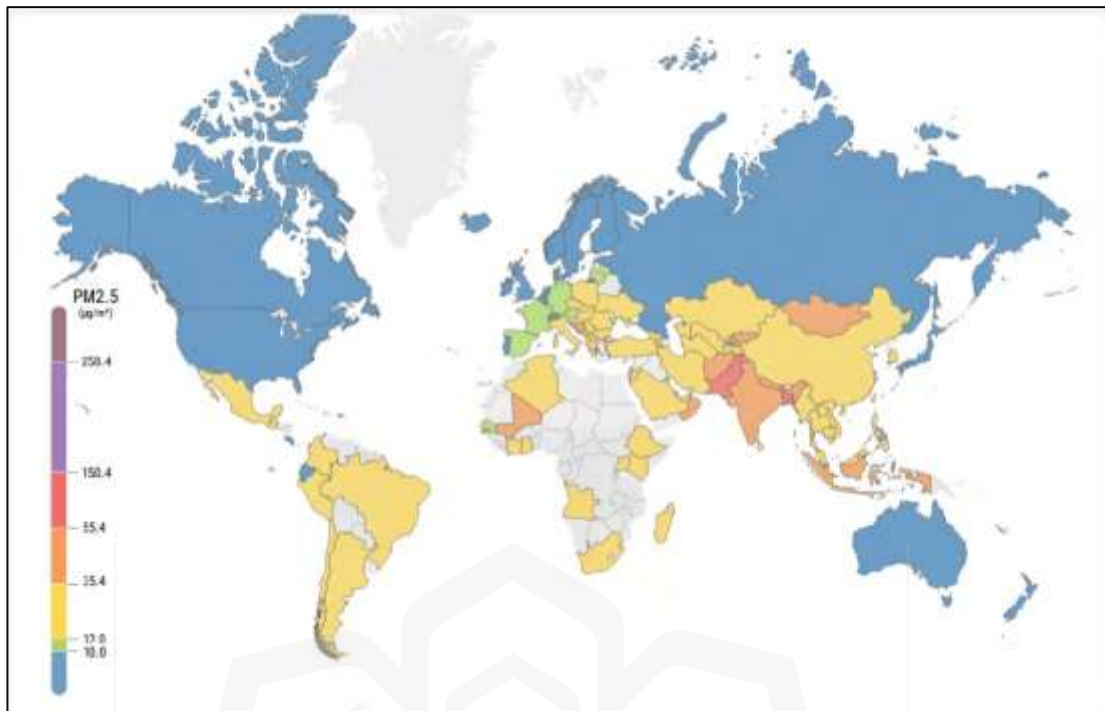


Figure 0.5 Countries and regions South Asia, Southeast and East Asia exposure to annual average $PM_{2.5}$ concentration. Note. The countries are labelled according to the based target of WHO. (+IQAir Report, 2023).

According to table 1.3 showed that the US Air quality index (US AQI) that used by Malaysia as benchmark for comparing and reporting air quality data. The Department of Environment managed the air quality monitoring, uses the same AQI scale to inform citizens of the status of current air quality and help the public to understand potential health risks impacts. The API system in Malaysia is aligned with the US AQI system, in classified the system warning as either moderate or unhealthy for sensitive group. Nevertheless, Malaysia should take a step forward by further reducing the minimum level of air emissions to a lower level. Malaysia should also be prepared to accept any change in US AQI air emission rates that are stricter in the future and be prepared to achieve that rate by taking serious and strict enforcement and inspection of the industrial sector. Air quality monitoring by DOE, whether through a continuous air data collection system or through periodic monitoring, should be analysed speedily to ensure that the emission of these pollutants is within the permitted emission status. The data analysis officer should understand the air quality emission rate well and report if there is any problem with the data obtained at a fast rate.

Table 0.3 United States Air Quality Index (US AQI) Note: US AQI is used as a benchmark for the world rating system. (+IQAir Report, 2023).

US AQI Level		PM _{2.5} (g/m ³)	Health Recommendation
Good	0-50	0-12.0	Air quality is satisfactory and poses little or no risk
Moderate	51-100	12.1-35.4	Sensitive individuals should avoid outdoor activity as they may experience irritation and respiratory symptoms
Unhealthy for Sensitive Group	101-150	35.5-55.4	General public and sensitive individuals in particular are at risk to experience respiratory problems
Unhealthy	151-200	55.5-150.4	Increased likelihood of adverse effects and aggravation to the heart and lungs among general public.
Very Unhealthy	201-300	150.5-250.4	General public will be noticeably affected. Sensitive groups should restrict outdoor activities
Hazardous	301+	250.5 above	General public is at high risk to experience strong irritations and adverse health effects Everyone should avoid outdoor activities.

In the year 2019 and 2020, Malaysia saw some decline in world country ranking from 50 to 58 but the US AQI level is still at a moderate level. However, if compared to ASEAN (Association of Southeast Asian Nations), Malaysia is placed in a better position than ASEAN countries for ranking air pollution (IQAir, 2019 and 2020). Table 1.4 shown Malaysia was ranked in place on 58th in the year 2020 and 50th place in the year 2019. In the year 2020, the PM_{2.5} concentration was 15.6 µg/m³ respectively, and in the year 2019, the PM_{2.5} concentration was 19.4 µg/m³ respectively. In both years, Malaysia serves to rank as “moderate” under US AQI. Malaysia showed slightly over the target recommended by the WHO which is 10 µg/m³ (IQAir, 2021). However, compared to many ASEAN countries, Malaysia still holds a better position in terms of

air quality. The decline in rankings serves as a reminder that while progress is being made, continued efforts are necessary to reduce air pollution and improve public health.

Table 0.4 World country ranking for the country of Malaysia in the years 2019 and 2020. (+IQAir Report, 2020).

Year	PM_{2.5} concentration ($\mu\text{g}/\text{m}^3$)	World Country Ranking	US AQI level
2020	15.6	58	Moderate
2019	19.4	50	Moderate

The ambient air quality measurement in Malaysia known as the Air Pollution Index (API) was monitored closely by the Department of Environment. API closely followed the pollution standard Index (PSI) developed by the United States Environment Protection Agency. The air quality standard in Malaysia was established in 1989 as we follow other countries such as the US, in mitigating and controlling pollution in ambient air. The standard was used to protect human health and it is applied to all states in Malaysia. Due to the history of the Department of Environment (DOE), a set of air quality guidelines known as Recommended Malaysian Air Quality Guidelines (RMG) was developed to define the concentration of selected air pollutants that may adversely affect humans. The RMG brought in emerging the first formulated air quality index system known as The Malaysian Air Quality Index (MAQI) in the year 1993.

The index system determines the status of the ambient air quality for the decision makers and public civilians to work closely to define the quality of air ranging from good to hazardous. Table 1.5 shown the API calculation was later adopted to determine the Recommended Malaysia Air Quality Guidelines. The RMG contains five (5) air pollutant criteria as Ozone (AS 2524), Carbon Monoxide (AS 2695), Nitrogen Dioxide (AS 2447), Sulphur Dioxide (AS 2523), and PM₁₀ (AS2724.6) (DOE, 2000). The API system is calculated using five major pollutants (Nitrogen Dioxide, Carbon Monoxide, PM, Sulphur Dioxide and ozone), to gain API value by assessing the concentration pollutants. Each concentration pollutants is measured at various air monitoring stations

either in rural or rural area. The API calculation is an important value for Malaysia to determine the mitigation strategies for local authority and government agencies to combat the health issues to ensure the heathier air condition for all Malaysian to live in.

Figure 1.5 showed countries and regions South Asia, Southeast and East Asia exposure to annual average PM_{2.5} concentration according to WHO. WHO reported that South Asia includes some of the most polluted countries in the world, with India, Bangladesh, Nepal, and Pakistan consistently facing some of the highest levels of PM_{2.5} in the country. These countries typically exceed the WHO's annual average PM_{2.5} target of $\leq 10 \mu\text{g}/\text{m}^3$, placing them in the "Very Unhealthy" or "Hazardous" categories. Whereas, Southeast Asia is also heavily impacted by PM_{2.5} pollution, especially during the haze season, which occurs due to forest fires in countries like Indonesia. Many countries in the region have PM_{2.5} concentrations that exceed the WHO guideline. Forest fires and peat fires, particularly during the haze season in countries like Indonesia and Malaysia, significantly increase PM_{2.5} levels. This situation is difficult to contain when both countries carry out open burning simultaneously and are not closely monitored and controlled to ensure that the fire is completely extinguished after the burning activity is completed.

Table 0.5 Malaysia Air Pollution Index. Note: The air quality is reported in means instead of the actual air quality concentration of air pollutants by the Department of Environment. (DOE, 2015).

Air Pollution Index (API)	Status
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very Unhealthy
>301	Hazardous

Twenty-four years later, in 2013, the DOE came up with a New Malaysia Ambient Air Quality Standard to replace the Malaysia Air Quality Guidelines. The air pollutant criteria were added from five to six parameters and the five (5) of the

parameters before are still maintained with an added new parameter of PM_{2.5}. PM_{2.5} is an atmospheric particulate matter with a size of less than 2.5 microns. They are known as fine particulate and their size is smaller than the size of PM₁₀. The DOE will strengthen the new standard under its three (3) interim targets set from the year 2015 to 2020. Table 1.5 The interim target set includes the interim target (IT-1) in 2015, interim target 2 (IT-2) in 2018 and 2020, and full implementation of the standard. The 3 interim targets are set in the table below. In the interim, however, the target will be reviewed from time to time and depends on the capacity building, assessment of national needs and additional elements to be considered in the future (DOE, 2015).

The replacement from Malaysia Air Quality Guidelines to the new Malaysian ambient air quality standard determines that Malaysia is ready to achieve better air quality, where Malaysia has also signed the Kyoto Protocol and the Paris Agreement at the international level, which support a country to continuously monitor the national air quality. However, in Paris agreement, Malaysia faces the challenge of balancing industrialization and economic growth in its climate commitments. Malaysia still reliance on the fossil fuel for energy and other source such as coal in industries production process. This makes the emission reduction difficult to achieve the air quality status level without significant support. Financial support for the sustainable development, adaptation, and clean energy technologies received a high response from foreign financial aid at the beginning of the exposure, but the financial response is decreasing from year to year, and there are countries that no longer provide and offer this financial support to any country. This situation is very worrying because the industry will choose more economical combustion sources to reduce production costs in their factories. Other than that, the implementation advanced pollution control technologies such as electrostatic precipitator, scrubber and other filters, requires high investment and maintenance cost, to ensure these technologies is function perfectly and continuously during its operational. Therefore, the support from various government and private agencies is very important because these sources of air emissions from large and small industries have the same impact on Malaysian air pollution.

Table 0.6 New Malaysia Ambient Air Quality Standard. Note: The standard is applied in Malaysia and the latest standard in the year 2020. (DOE, 2015).

Pollutants	Averaging time	IT-1 (2015) $\mu\text{g}/\text{m}^3$	IT-2 (2018) $\mu\text{g}/\text{m}^3$	Standard (2020) $\mu\text{g}/\text{m}^3$
Particulate Matter, PM_{10}	1 Year	50	45	40
	24 Hour	150	120	100
Particulate matter, $\text{PM}_{2.5}$	1 Year	35	25	15
	24 Hour	75	50	35
Sulphur Dioxide, SO_2	1 Year	350	300	250
	24 Hour	105	90	80
Nitrogen dioxide, NO_2	1 Year	320	300	280
	24 Hour	75	75	70
Ground Level Ozone, O_3	1 Year	200	200	180
	8 Hour	120	120	100
*Carbon Monoxide	1 Year	35	35	30
	8 Hour	10	10	10

The air quality is known as the Air Quality Standard which is monitored by the Department of Environment of Malaysia (DOE) to detect any changes in the ambient air. It was monitored using two (2) types of equipment; Continuous Air Quality Monitoring (CAQM) and Manual Air Quality Monitoring (MAQM). The CAQM is an automatic monitoring device that is designed to measure gases in the air continuously for 24 hours. About 52 continuous stations were installed around the country which has been divided into 5 category stations that are industrial, residential, traffic, background and PM_{10} . The pollution gases that are closely monitored are Sulphur dioxide, Nitrogen oxides, Carbon monoxide, Ozone, Hydrocarbon, PM_{10} and UV. Another additional air quality data supplement is the MAQM which is a high-volume sampler to measure the particulate matter (PM_{10}), total suspended particulate (TSP) and several heavy metals such as iron, lead, mercury, copper, sodium etc. The MAQM is measured once every six days and the measurement are collected and delivered to a laboratory for details analysis.

1.3 STATEMENT OF THE PROBLEM

There are 30 by-laws enacted by the state government of Pahang and enforced by the Kuantan City Council. However, none of these by-laws are related to the monitoring, control, and management of air pollution. There are no guidelines specifically from the Kuantan City Council that monitoring, control and mitigate of PM_{2.5} emissions from construction areas. This makes it extremely difficult for the Kuantan City Council to monitor and control PM_{2.5} emissions regularly and comprehensively on any construction project carried out in its administrative area. This will be difficult when the Kuantan City Council also does not have any laws involving the release of PM_{2.5} from the construction area to take action if there is a violation of the conditions of approval given to the developer or project proponent.

The Construction Industry Development Board (CIDB) has a dust permissible exposure limit for PM_{2.5} known as respirable dust. In the Construction Industry Standard, under Guidelines for working in noisy and dusty areas in construction sites (CIS 17:2010) respirable dust refers to those particles that are small enough to penetrate the upper respiratory and deep into the lung. However, the exposure limits for respirable dust to be monitored in these guidelines are stated only 8 hours. According to New Malaysia, Ambient Air Quality Standard PM_{2.5} should be monitored for 24 hours to determine the presence of PM_{2.5} in the air. The time frame for monitoring PM_{2.5} in CIDB guidelines is a short period, and it is not relevant to present data wholly or partially on the air quality emissions from construction sites.

Environmental Quality Act 1974 (Act 127) is a Malaysian law that comprehensively preserves and protects the environment from environmental pollution. This law covers air pollution for industries such as bag filters, scrubbers and fuel burning under the Environmental Quality (Clean Air) Regulations 2014. However, no regulation, order or section covers monitoring and control of dust and gas emissions from construction sites. It is important to have regulation or order PM_{2.5} emission in ACT 127 to ensure the air pollution from construction areas is constantly monitored and emission rates are in compliance with Malaysia Ambient Air Quality Standard.

The effect air quality from the construction activity may cause serious health impacts on the people who are exposed to it. The uncontrolled emission of PM_{2.5} may cause negative impacts on human health when the time and duration of exposure are increased to several hours. Particulate matter can easily enter the respiratory system and cause serious health effects such as difficulty breathing, throat and lung irritation, coughing, sneezing, and shortness of breath. The chemical airborne particulate matter can damage the respiratory organs if exposed for a long period.

The dust, noise, liquid waste, and harmful gases may result from the construction process (Tah & Abanda, 2011). The airborne particulate matter that consists of liquid droplets and solid particles will be suspended in the air for a long period depending on varying composition, origin, and microscopic size (Dockery D.W., 1993). The particulate matter that is larger than 10 microns will be filtered in the respiratory tract through the nose, cilia and mucus. However, fine particulate matter can be inhaled deeply into the lung which is more toxic than larger particles and causes a great risk to human health (Dockery D.W., 1993). According to evidence by Jie Chen et al (2020), mortality is increased associated with lung cancer, respiratory disease and cardiovascular disease.

The availability of particulate matter in our atmosphere is in the form of microscopic either solid or liquid matter suspended. The PM builds in a complex mixture of inorganic and organic particles such as on-road vehicles, Off-road Vehicles, Unpaved roads, paved roads, fuel combustion, industrial processes, waste disposal, miscellaneous dirt, pollen, dust, liquid droplets, soot, smoke etc. PM consists of aerodynamic diameters ranging from ≤ 10 and ≤ 2.5 μm (PM₁₀ and PM_{2.5} respectively). PM is a mixture of particles from different sizes and sources, properties, and compositions. (Daniel, 2008). Larger particles ($> 10\mu\text{m}$ aerodynamic diameter) from a source such as smoke or soot, while very small particles ($\leq 2.5\mu\text{m}$) are apparent indirectly from the process of diffusing, reflecting light, absorbing, and diffracting. PM can be directly emitted into the air by stationary sources such as factories, open burning, power plants and mobile sources (moving vehicles). Nevertheless, non-point sources of particles from agricultural activities, mining and construction contribute also to the PM in the air.

PM comes from various sources during the construction site activity, especially in the site preparation phase. During the site preparation phase, activities such as site clearing, earthworks activities such as cutting and filling, and construction of temporary access roads may cause high PM emissions. The emission of PM might be due to the removal of plants from the site. The use of high-impact vehicles such as excavators, shredders, tractors, and dump trucks may cause fugitive dust to emit directly into the atmosphere. Roadside moving vehicles may also cause PM emissions. Construction equipment usage at transportation projects is a source of both fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter (Ingrid et al., 2014).

Exhaust from diesel-powered construction equipment includes fine particles (primary $PM_{2.5}$) and other pollutants that contribute to the formation of $PM_{2.5}$ in the atmosphere (secondary $PM_{2.5}$). In addition, the use of construction equipment loosens and disturbs soil; the resulting windblown (or fugitive) dust can contribute to $PM_{2.5}$. Bulk material operations on construction sites, such as rock crushing, blasting, and drilling activities, can also contribute to windblown dust (Cohen, 2005). Exposure to $PM_{2.5}$ from construction to a nearby residential area may cause health effects, especially to a person who suffers from respiratory and cardiovascular mobility. Exposure to $PM_{2.5}$ in the long term may cause mortality from cardiovascular. Applying the study of spatial distribution, the concentration of $PM_{2.5}$ can be identified, and the pattern of distribution can be determined (Cohen, 2005). Research findings by Hui Yan et al. (2023) stated that hammer piling, materials transportation and waste stacking during the foundation construction stage and earthwork phase, are the main activities causing PM emission at site.

Construction activities have an impact on sustainable development (Wetherill et al., 2007; Pinkse and Domisse 2009; Pitt et al., 2009) because they produce waste that causes resources and environmental pollution, also adversely affecting neighbouring communities and even public health in general (USGBC 2001; Holton et al., 2008). Based on the research done by Celik et al. (2016) the most disturbing nuisance is dust where in the study the neighbourhood experiences loss of quietude and peace among subcategories survey. One of the principal environmental impacts caused by construction is related to the atmospheric pollution resulting from the emission of particulate matter (Chang et al., 2014; Sey 2009). PM is a group of polluting agents

consisting of dust, smoke and all types of solid and liquid material that remain suspended in the air because of their small size and they are light (U.S. EPA 1996; CEQA 2012).

The PM released during the construction operations causes an impact on local air quality involving activities such as burning equipment, exhaust particulate from machinery equipment and availability of suspended dust. In construction, especially during the execution of a project, there is a daily generation of PM from various phases, including demolition, earthmoving work, structures, seals and finishing (Chen et al., 2011; Muleski et al., 2005). The emission mechanism of PM is related to the speed of the wind during the development of construction activity on job sites. During these activities, different types of PM were generated affecting the workplace and the surrounding areas (U.S. EPA 2004; Chang et al., 2014)

1.4 RESEARCH OBJECTIVES

Air pollution from the construction site area needs to be pointed out since this air quality will negatively affect the surrounding area. However, our country still does not emphasize the importance of continuously monitoring PM_{2.5} from the construction site. Our environmental enforcement agency does not have any legal document that states “a must” to monitor the emission of PM_{2.5}. The objective of this study is to encourage the continuous monitoring of particulate matter, which is important in maintaining air quality more efficiently and effectively. Effective objectives will lead to a more accurate direction and can reduce costs Therefore, the study's objectives need to be implemented to support the research.

- i. Determine various concentrations of PM_{2.5} emitted from the construction site activities.
- ii. Identify the sources/activities of significant components of PM_{2.5} emanating from a construction site.
- iii. Analysis of data collection using meteorological software and environmental modelling.

- iv. Mapping the $PM_{2.5}$ prediction dispersion on Google Earth for map visualisation.
- v. Gain recommendations and solutions from the research investigation done.

For better understanding, these objectives are explained in Chapter 3, until Chapter 6.

1.5 SCOPE OF THE STUDY

The proposed investigation of the research is to provide better information and awareness about the nature of $PM_{2.5}$ concentration available in our atmosphere, especially at the construction site which may affect the health and safety of workers and nearby residents.

- i. The source emission of $PM_{2.5}$ from various activities at the construction site from different exposure times, type of activities involvement and frequency of activities.
- ii. The meteorological data plays an important role in the distribution of $PM_{2.5}$ that can be occurred in short and long-period studies. The meteorological data is supporting data in this research to gain map visualization from the combined analysis.
- iii. The international studies organized by several government agencies and private agencies determine that $PM_{2.5}$ need to be seen as a serious matter and this was supported by several local newspapers and local tv news broad the particulate matter issues as problematic and tragic to the health effect and safety.
- iv. Factors affecting $PM_{2.5}$ dispersion will involve various factors, and they need to be clearly defined through research investigation.

1.6 SIGNIFICANT OF RESEARCH

The findings of this study will change the perspective of the Malaysian community on the importance of controlling and monitoring the air quality, especially PM_{2.5} emissions from construction sites. The emission of PM_{2.5} from the construction may lead to huge issues of community combat with government agencies or project proponents if the project takes a long time to complete. The emission of dust containing PM_{2.5} will affect the health of people who are exposed to it every day and for a long period.

From a positive point of view, environmental technologists will create air monitoring tools that will monitor the PM_{2.5} at home or at the office. The production of equipment will boost the economy and increase employment opportunities for Malaysians to be involved in innovation at the local or international level. Malaysia will get funds from Germany, Japan, China or Europe to support the participation of innovators in innovative activities that will encourage technological air pollution technology, air pollution control tools, software or equipment that have the potential to be commercialized.

In 2023, Malaysia is rank in 38 of 134 countries in the World Air Quality Report 2023 on PM_{2.5} by the World Health Organization (+IQAir, 2023). The rank shows that PM_{2.5} in Malaysia's atmosphere is increased by 30% from 17.7 µg/m³ to 22.5 µg/m³. Kuantan experienced an annual average of 17.1 µg/m³ in 2023 compared to 10.3 µg/m³ in 2022. Malaysia is shot up to be worst in air quality PM_{2.5} in coming years. The trend shows the concern of air quality in our country which is deteriorating and very dangerous to health. This study will help to control the emissions of PM_{2.5} from construction sites one of the contributions to the emission of PM_{2.5} into the atmosphere. It is important to ensure the emission of PM_{2.5} within the standard is before is it an indicator for tourists to come to our country. The better the air quality, will increase the number of tourists to our country.

The residential communities start to open their eyes to being involved in local issues discussions with project proponent or government agencies and monitoring particulate matter less than 2.5 microns (PM_{2.5}) emissions from construction sites adjacent to their neighbourhood. Understanding and raising awareness of the impact of

PM_{2.5} on health effects has made the community fight the clean air quality to breathe and to monitor the air quality within the standard. Exposure to PM_{2.5} can lead to chronic respiratory disease and other chronic obstructive pulmonary disease (COPD) as PM_{2.5} has a diameter of 2.5 micrometres or is even smaller, able to penetrate deep into the lungs and enter the human bloodstream. The community will make an effort to monitor through self-monitoring PM_{2.5} by purchasing household PM_{2.5} equipment monitoring devices based on the laser and infrared principles such as HT-9600 (Atel, 2024), Temtop M2000 2nd Generation (Temtopus, 2024) or Aeroqual Series 500 (Aeroqual, 2024). This equipment is available in the market to purchase and it is easy to use.

The PM emission from the construction site should comply with the standard emission in our country. The New Malaysia Ambient Air Quality Standard 2013 (MAAQS) has set the standard limit of PM_{2.5} between 2.5 to 35 µg/m³ for a 24-hour average. To comply with this standard, it is important to monitor on-site the emission of PM_{2.5} in the construction area to avoid the emission of PM_{2.5} over the standard limit. Continuous emission monitoring should always be ongoing to keep the data emission constant secure and vulnerable to analysis. Currently, PM_{2.5} is not monitored continuously on the construction site, and it is hard to generate a database sequence to model the emission of PM_{2.5}. The sequences database will be used as a reference in future studies to analyze pattern distribution.

Construction Industry Development Board (CIDB) has a sustainability rating tool known as the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) to quantify and lower the carbon footprint of construction projects from the design phase, during the construction stage and operation and maintenance stage of the building in a sustainable manner and with very low-carbon reduction. MyCREST focuses on carbon sequestration, carbon reduction and carbon impact. During construction, most of the emissions are particulate matter in dust from the soil that is emitted from the movement of the vehicle, during clearing land, excavation, and other related activities. However, none of the PM_{2.5} components consist of the MyCREST rating tool. PM_{2.5} needs to be measured in its concentration as this PM is one of the air pollutant parameters in MAAQS. That is why this study is important to be carried out to justify the importance of PM_{2.5} to be measured in construction sites.

The use of R studio software in the study produces impact mapping of $PM_{2.5}$ at the project site by visualising the $PM_{2.5}$ in the Bivariate Polar Plot. Bivariate Polar Plots are a common method in presenting the exploring pollutant $PM_{2.5}$ with other concentrations such as wind direction and wind speed. According to Carslaw et al. (2012), package openair has shown that a bivariate polar diagram is another innovative technique for the R programming environment. Investigated determined by Szulecka et al. (2017), the potential direction of gases and their correlation with each wind sector depends on meteorological conditions such as wind speed and wind direction. Figure 1.6 is an example of a bivariate polar plot concentration graphed conjunct with wind direction and wind speed. The plot makes it easier to view the pattern distribution rather than interpret data using a table.

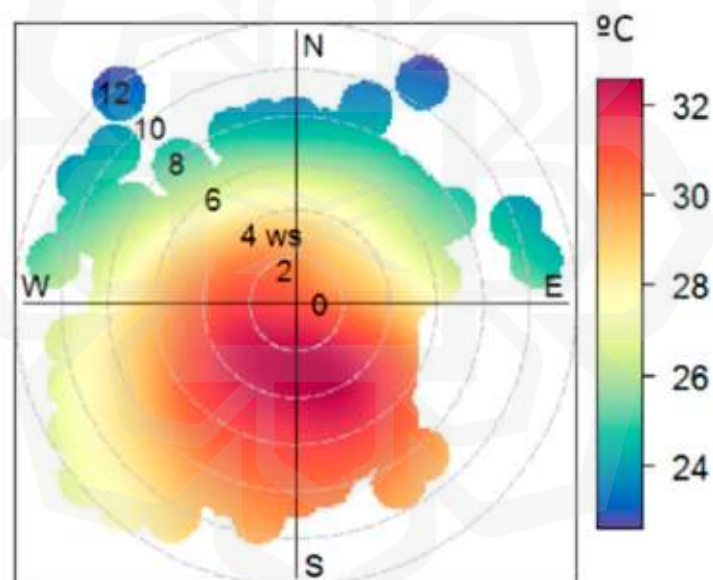


Figure 0.6 Example pattern distribution using the bivariate polar plot. (Carslaw, 2006)

In this research, clarify that meteorological factors such as humidity, amount of rainfall, temperature, wind speed and wind direction need to be counted and determined as a contributor to the dispersion and transportation of $PM_{2.5}$ within or beyond the construction area. The wind speed and wind direction will be analyzed using environmental modeling to predict the area of dispersion of $PM_{2.5}$ using wind direction and wind speed as variables in the modeling. From the research analyses, we will

originate solutions and recommendations to the problem that occurs in the research study.

1.7 CONCLUSION

The monitoring of $PM_{2.5}$ at construction is important to be monitored continuously and periodically. Many studies have been carried out on $PM_{2.5}$ and it show that $PM_{2.5}$ is one of the contributing factors to the pollution of air quality from the construction site. $PM_{2.5}$ can be released from 2 primary stages of a construction project that are construction phase and the post-construction phase. Particulate matter can be emitted either during the day and night depending on the time of the construction.

$PM_{2.5}$ can be harmful to the respiratory system as $PM_{2.5}$ can penetrate deep into the lungs causing asthma and chronic obstructive pulmonary disease (COPD) in asthma patients, children, and the elderly. Many studies and research have been done from 2000 until now on the impact of health exposure to particulate matter. This shows how serious the impact of particulate matter is on humans and the environment if the particulate matter is not being monitored periodically. Long-term effects on the respiratory system such as affecting to lungs, developing chronic hypertension, and capable to triggering autonomic nervous system imbalances.

Particulate matter may affect the environment and could cause degradation of the material, especially on historic buildings, monuments and statue. The degradation of the material will be increased the cost in restoration as the damage to the material is irreversible and enormous. The chemical concentration compound in the atmosphere will cause corrosion and soiling to cause destructive and loss of the unique of cultural heritage.

Monitoring the $PM_{2.5}$ at construction should be a compulsory in daily air pollution monitoring to comply with the Malaysia Air Quality standard and to ensure the concentration of $PM_{2.5}$ emitted from construction site a not harmful to the surrounding environment.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The emission of air pollutants from construction is the main environmental concern because it may impact the air quality in the nearby surrounding area. The dust from the activity of the construction site was both fine and coarse particulate matter. Particulate matter in fine course able to stay in the atmosphere and travel long distances by wind then it can settle on the ground or in the water. The settling of the particulate matter can have a serious effect on the environment depending on the chemical composition inside the particulate matter. If the construction is adjacent to a museum, zoo, or historical building, the prolonged exposure of particulate matter can stain and damage the material of the building and cause a loss of strength in the building structure.

In Chapter 2, the emission of $PM_{2.5}$ from the construction site and its physical properties will be discussed. Other than that, the explanation of the previous researcher on the methodology and method was reviewed about the meteorological data, WRPLOTs, and Rstudio methods used in generating dispersion patterns of particulate matter $PM_{2.5}$.

2.2 STUDIES OF PARTICULATE MATTER IN CONSTRUCTION SITE

Particulate matter in the atmosphere is made up of liquid and solid that discharge directly as a result of agriculture and road dust, industrial activity, and diesel use; PM remains suspended in the air because of its size, density and influence of wind speed (Yang et al., 2018). Much PM_{10} concentration identified at construction sites arises from local fugitive sources such as vehicle exhaust and non-vehicle exhaust sources. However, there is still very little work or less research focused on $PM_{2.5}$ fractions arising from construction activities (Farhad et al., 2016). According to the United States, limited research on $PM_{2.5}$ has been done to identify the important sources of particulate

matter emission from road and building construction activity (Muleski et al., 2011). Azarmi et al. (2016) the assessing studies of the contribution of PM₁₀ and PM_{2.5} to the surrounding air quality are limited.

Despite knowledge of this, Ab. Rahman (2022) stated that in air quality monitoring in Malaysia, particulate matter is the most concern where the Department of Environment (DOE) has recorded continuous data through the Continuous Air Quality Monitoring Network by using a tapered element oscillating microbalance. Due to rapid development and urbanization, PM_{2.5} have effects on air quality Li et al. (2020, 2021) claim that Middle Eastern countries such as Iran, Iraq and Saudi Arabia suffer high concentrations of PM_{2.5} in airborne dust.

2.3 SOURCE OF PM AT THE CONSTRUCTION SITE AND ISSUES.

The emission of particulate matter at construction sites hurts human health also the environment. Studies have shown that about 0.8 million premature deaths and about 6.4 million years of life lost were due to air pollution caused by PM_{2.5} (Aaron et al., 2005). Many studies indicate that particulate matter can cause mortality as low as 80 µg/m³. The chemical and noxious gas suspended in the air may enter the body through inhaling causing injuries to delicate tissues in the respiratory tract (Trivedy et al., 2015).

Some sources may emit particulate matter from the construction site from various activities such as clearing of land and other related activities such as compaction and excavation, operation of heavy machinery and equipment related to construction and earthmoving purposes (cranes, bulldozer, excavator, etc.) and the engines associated with such machines, erection of structure using timber, steel, glass, concrete other materials, mechanical activities including demolition, grit blasting, drilling, grinding and hammering, finishing and metal. joining including soldering, brazing, welding, and other techniques, generation of solid wastes and debris, their stockpiling and transfer through chutes and loading onto trucks or wastes off-site, transport of building materials and supplies onto the site, and transfer of wastes off-site, movement of vehicles along roadways paths, in and out of the site and within the site (NSW, 2017)

The generation of dust, gaseous pollutants, particulate matter, noise, and other atmospheric contaminants resulting either indirectly or directly from building construction activities. However, several sources that generate the pollutants are associated with mobile machinery (not restricted to roads) as well as construction works and onsite machinery (off-road emission). The emission of PM depends on different activities, and it has no clearly defined use by the builder on management control method and technology being used (Chowdhuri et al., 2017). The emission of PM_{2.5} mostly will be in short periods and will not last for a longer period in one place depending on the time frame of the construction period and activities (Putri Shazlia, 2019). The baseline data for PM_{2.5} can be established by maintaining proper schedule construction time management at the construction site to obtain data for mapping the pattern distribution of PM_{2.5} concentrations (Putri Shazlia, 2019). The study was done in South Korea, PM is the fugitive dust that is directly related to the construction site (Kim et al., 2021).

The construction site needs to control and monitor its emission of particulate matter by having a proper schedule for construction time management at the site. The baseline data for PM_{2.5} needs to be established also to measure and the mapping the distribution pattern of PM_{2.5} from source emission at the construction site. From the baseline data, modelling of PM_{2.5} can be used to understand the prediction of emissions in construction activity

2.4 METEOROLOGICAL INFLUENCE ON PARTICULATE MATTER

Cheewinsiriwat et al. (2022) have justified that meteorological factor influences PM_{2.5} through traffic and land use. Meteorology data also affects transportation distribution and the formation of PM in the air. The dispersion processes, chemical formation of PM, and removal mechanism depend on parameters such as temperature, wind speed, solar radiation, humidity, atmospheric pressure, and rainfall rate (Galindo et al., 2010). Keary et al. (1998) have explained that studies have been done in several urban places to investigate the relationship between meteorological variables and PM levels.

In Dublin, PM₁₀ mass concentration was decreased with an increase in wind speed, precipitation rate and temperature due to increased traffic density, and domestic heating during winter showed a negative correlation between PM₁₀ and temperature. Different studies have been done specially focused on the role of wind and temperature on the variability of PM levels. (DeGaetano et al., 2004; Rigby et al., 2006; Richmond-Bryant et al., 2009).

A study conducted on air quality in Ohio showed the wind blowing from south and southeast with wind speeds below 8 mph and temperature 70°F showed that the wind direction, temperature, and wind speed have significantly influenced PM_{2.5} concentration (Lee et al., 2002). The emission concentration of particulate matter in the construction site at Bangalore is influenced by the weather condition variables including velocity, wind direction and other local conditions (Chowdhuri et al., 2017). The different wind speeds influenced PM_{2.5}, the stronger wind could blow the particulate matter far away and suspend coarse particulate matter in the air (Pengjan et al., 2019). Liu et al. (2020) evaluated that PM_{2.5} also may be influenced by the difference in wind speed.

2.5 PARTICULATE MATTER AND ITS HEALTH IMPACT

People who work and live in nearby surrounding construction areas may get health effects from the emission of PM. The ultrafine (PM_{≤ 2.5}µm in diameter) have the potential to enter the lung and also get into the bloodstream. The fine particles are also can cause several effects on our body. Numerous scientific studies have been done that the exposure of these fine particles in our body can cause several problems such as premature death with heart or lung disease, irregular heartbeat, aggravated asthma, decreased lung function and increased respiratory symptoms such as irritation of airways, coughing or difficulty breathing. Exposure to PM_{2.5} may reduce eye visibility (haze) (EPA 2017).

Thurston *et al.* (1994); Schwartz *et al.* (1996), and Pope (2000) have assessed when the airborne concentration of PM_{2.5} increases, it affects the number of people's health in the cities' Respiratory illnesses such as changes in heart rhythms, respiratory

problems, severe respiratory and heart attacks and heart malfunctions leading to death. Due to upsurges of airborne concentration in the atmosphere, more absences happened in school and workplace studies have shown that every $\text{PM}_{2.5}$ decline of $10 \mu\text{g}/\text{m}^3$ of air, decreases 15% of the risk of heart disease deaths (CDC, 2013). Figure 2.1 shows the route of exposure to $\text{PM}_{2.5}$ into the heart and lung. The smaller $\text{PM}_{2.5}$ easily get into the deep of the lung enters the circulatory system and remains embedded for long periods (Utah, 2019).

Research has been done that looks at how PM size and type affect the hazardous dose. Lin et al. (2020) studied that the different two types of parameters, namely, size and material will make a difference in the dangerous dose of exposure. Zou et al. (2017) and Tjoe et al. (2003) found that serious health risks to construction workers are very high if exposure to PM at this suspended rate at high concentrations, major health. This evidence somewhat confirms that in 2010, a statement was issued by the International Agency for Research on Cancer classifying suspended PM as a group 1 carcinogen (carcinogenic to humans) by IARC (2012). The findings by Lashgari (2013) stated that the use of appropriate equipment can also reduce exposure to the amount of $\text{PM}_{2.5}$ and PM_{10} and exposure time.

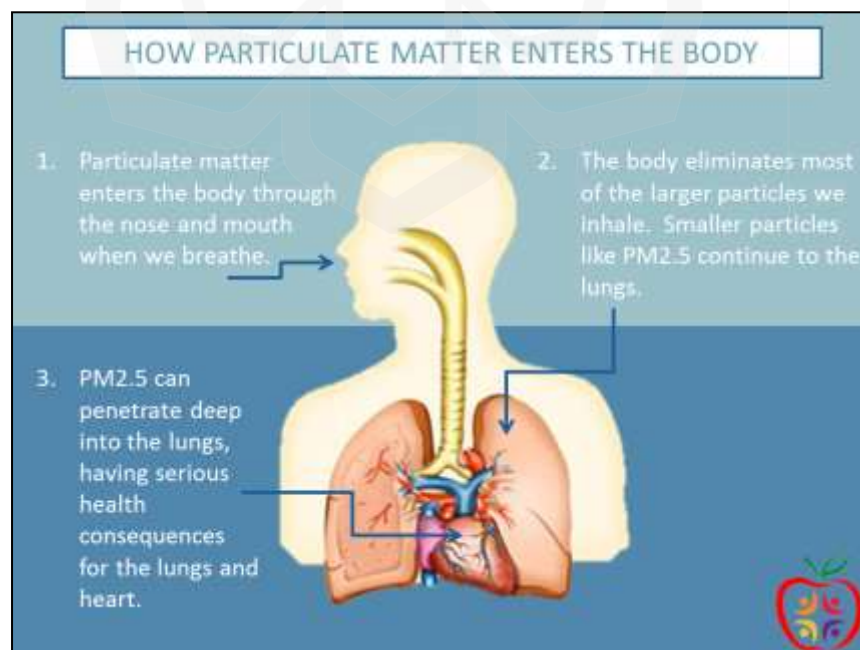


Figure 2.1 The flow of particulate matter enters the body.
(Washington State Department of Ecology, 2018)

According to Global Health Observatory (GHO) data in 2016, the population living exposed to particulate matter in the cities was about 90% exceeding the WHO air quality guidelines. The air quality guideline is an annual mean concentration for particulate matter set by WHO. The research stated the guideline stipulates that PM_{2.5} not exceed 10 ug/m³ yearly mean or 25 ug/m³ for 24 hours mean, and PM₁₀ not exceed 20 ug/m³ annual mean or 50 ug/m³ for 24 hours mean. Figure 2.2 shows the annual mean concentration of fine particulate matter (PM_{2.5}) in urban areas (ug/m³) by WHO region 2016. Starting from India (68 ug/m³), Bangladesh (58.6 ug/m³), Bhutan (35.4 ug/m³), Myanmar (34.6 ug/m³), Democratic People's Republic of Korea (31.0 ug/m³), Thailand (26.6 ug/m³), Timor-Leste (18.2 ug/m³), Indonesia (16.4 ug/m³) and Sri Lanka (15.1 ug/m³), except Maldives (7.7 ug/m³) showed the annual mean concentration of fine particulate matter in urban areas were exceed the air quality guideline set by the WHO.

Malaysia also showed that our annual mean concentration of fine particulate matter in urban areas exceeded the WHO air quality guideline with 17.3 ug/m³ (WHO, 2016). A group of vulnerable people such as those with heart disease or pre-existing lungs including children and elderly people are extremely threatened to highly exposed PM. The effect on children in a long exposure to PM could cause reversible deficits in lung function and also diminish lung growth rate and lung functions in a long term. In this matter, there is no evidence that a safe level of exposure or a line of threshold would cause no adverse effect occurred (WHO, 2013).

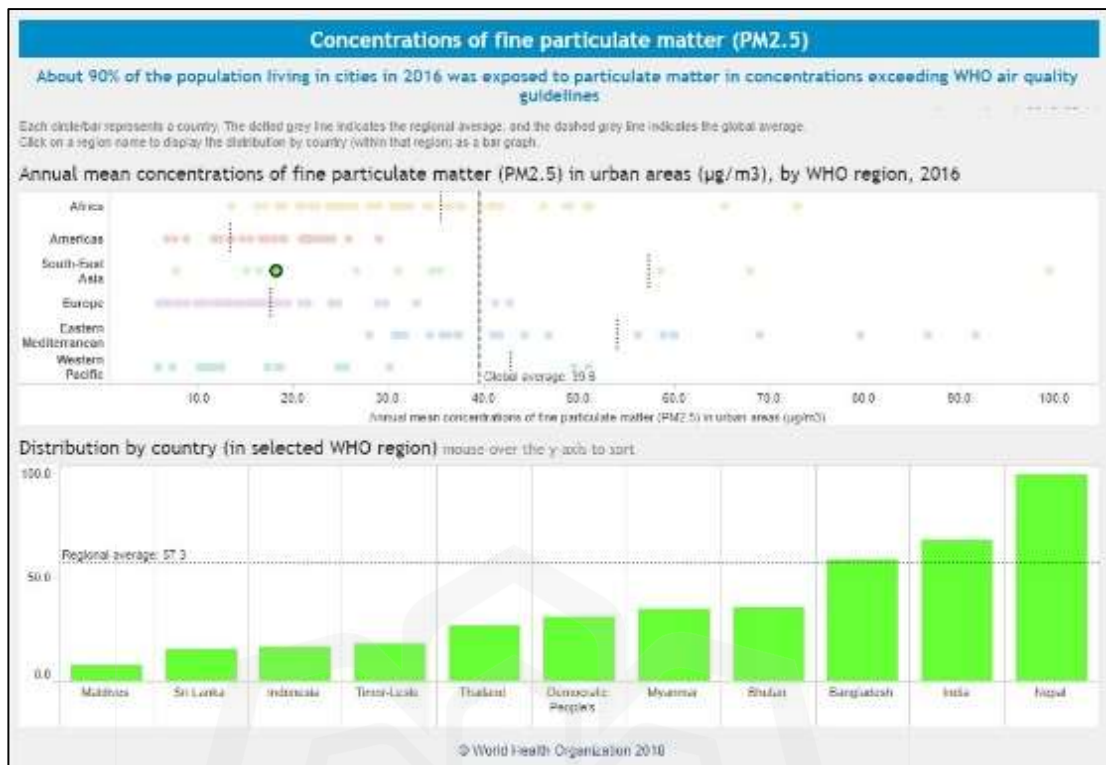


Figure 2.2 Concentration of fine particulate matter (PM_{2.5}) in an urban area (ug/m³). (WHO, 2016)

2.6 AIR QUALITY STANDARD GUIDELINES

The New Malaysian Ambient Air Quality Standard is under the purview of Environment Malaysia. The air quality was established in 1989 but has been substituted with the New Ambient Air Quality Standard for better air quality and environment and suitable for the current air quality pollution in the country. Therefore, air pollution from industries or another development sector would comply with the permissible limits that allow pollution. Table 2.1 shows the New Ambient Air Quality maintains the six (6) air pollutants criteria components including carbon monoxide (CO), sulfur dioxide (SO₂), ozone (O₃), nitrogen dioxide (NO₂), and particulate matter less than 10 microns (PM₁₀) as well as particulate matter less than 2.5 microns (PM_{2.5}). This standard was reviewed by the Department of Environment (DOE) in 2015 to enhance the air quality in current years. However, the DOE can review the standard again depending on the current air status situation.

In 2013, the DOE has reviewed the previous standard rate so that it matches the current development release rate. This new standard rate study will help the DOE in reducing pollutant emission rates by providing a maximum standard rate that is appropriate and able to be implemented by all parties. DOE (2016) has stated 2 features will be involve that is assition to a new parameter which is particulate matter size less than 2.5 micron (PM_{2.5}) and revised concentration limit.

Table 2.1 New Malaysia Ambient Malaysia Air Quality Standard (DOE, 2013)

Pollutants	Averaging Time	Ambient Air Quality Standard		
		IT-1 (2015)	IT-2 (2018)	Standard (2020)
		µg/m ³	µg/m ³	µg/m ³
Particulate Matter with a size of less than 10 Micron (PM ₁₀)	1 Year	50	45	40
	24 Hour	150	120	100
Particulate Matter with a size of less than 10 Micron (PM _{2.5})	1 Year	35	25	15
	24 Hour	75	50	35
Sulfur Dioxide (SO ₂)	1 Year	350	300	250
	24 Hour	105	90	80
Nitrogen Dioxide (NO ₂)	1 Year	320	300	280
	24 Hour	75	75	70
Ground Level Ozone (O ₃)	1 Hour	200	200	180
	8 Hour	120	120	100
Carbon Monoxide (CO)	1 Hour	35	35	30
	8 Hour	10	10	10

Malaysia has two (2) interim targets (IT) for Particulate matter (PM_{2.5}) in the years 2015 and 2018 before it achieved the Ambient Quality Standard in the year 2020. The PM_{2.5} interim target is a milestone development in progressing health-based air quality management and planning. The average time IT-1 until 2015 for 1 year is 35 µg/m³ and for 24 hours is 75 µg/m³. In the year 2016-2018, Malaysia must comply with the IT-2, 1 year for 25 µg/m³ and 24 hours for 50 µg/m³. However, counting to the year

2020, in two years times, Malaysia must comply AQS with 1 year for 15 $\mu\text{g}/\text{m}^3$ and 24 hours for 35 $\mu\text{g}/\text{m}^3$. Malaysia for better air quality, the $\text{PM}_{2.5}$ values will become more stringent to produce healthier air pollution for Malaysia.

Table 2.2 shows the summary of $\text{PM}_{2.5}$ ambient air quality guidelines valued for several countries. The guideline was used to control and reduce the pollutants and meet the specific conditions. The 24-hour value is defined as the daily average concentration measured while for annual mean is defined as the weighted annual mean for the year. The values of each country will differ depending on emissions sources, geographic location, economic conditions, scientific evidence of the toxicity of specific pollutants and monitoring duration (WHO, 2005).

The guidelines and values were applied differently in each country on its standard philosophy. According to Noel de Nevers (2000), the air quality standard philosophy is built from the threshold value situation from the assumption of the true situation of most major air pollution. However, the good of cost-effectiveness of standard philosophy done in a particular country depends on but it may not be excellent.

In order to ensure the pollutants emitted meet the standard, it is quite difficult to control certain sources of pollutants. For example, if pollutants are emitted from industry, enforcement can be done, and action can be taken. But what happens if, the pollution is from non-sources, the action can't be taken by the polluters as we do know who contributes to the pollution. The statement is supported by Noel (2000), who stated that assigning responsibility is easy if the pollutant has only one major source. But if the pollutant is produced by a variety of sources, and it is a secondary pollutant, for example, ozone, assigning the responsibility would be difficult and complex. As we can see, it is quite tough to control the concentration of the pollutants emitted into the atmosphere where the location of polluters can be far away or nearby. Investigation studies from Bran and Srivastava, 2017; Chandra *et al.*, 2017; Guo *et al.*, 2017; and Mukherjee and Agrawal (2018) agree that using the PM component analysis utilizing sophisticated source apportionment techniques such as community multi-scale air quality (CMAQ), climate model, positive matrix factorization, principal component analysis and EPA chemical mass balance model have identified the sources potential emission.

Table 2.2 Air quality guidelines PM_{2.5} for several countries.
(Arideep Mukherjee and Madhoolika Agrawal, 2018)

Country	24- Hour	1 Year	Reference
WHO	25.0	10.0	WHO(2005)
	75.0 (IT-1)	35.0 (IT-1)	
	50.0 (IT-2)	25.0(IT-2)	
	37.5(IT-3)	15.0(IT-1)	
US EPA	35.0	12.0 (Primary)	US EPA(2015)
		15.0 (secondary)	
China	35.0 Class 1	15.0 Class 1	GB-3095(2012)
	75.0 Class 2	35.0 Class 2	
India	60.0	40.0	CPCB(2009)
Europe		25.0	EEA(2013)
Australia	25.0	8.0	NEPM (2002)
Canada	30.0 (Before 2015)	10.0 (2015)	ECC(2013)
	28.0 (2015)	8.80 (2020)	
	27.0 (2020)		
Mexico	65.0	15.0	NOM (2005)
Bangladesh	65.0	15.0	Begum et al. (2013)
Thailand	50.0	25.0	PCD(2010)
Japan	35.0	15.0	EQSJ (2009)

2.7 THE METEOROLOGICAL DATA PROCESSING

Meteorological information has become more valuable to many researchers, educational or to everyone who wants to apply and use that information for their tasks or work in everyday life. Food production, plantation sector, construction sector, oil and gas industry, and other sectors used real-time meteorological data for planning, data observation, and improving decision-making support systems (Samet et al., 2010). In Malaysia, meteorological information is free for public users upon request and approved by the Malaysian Meteorological Department.

The combination distribution of wind speed and wind direction produces an accurate result in the estimation of pollution dispersion (Hossain & Easa, 2012). The wind rose represents the frequency of occurrence of winds for a specified period and site by each particular wind direction and wind speed. By obtaining period data such as a particular year or month the wind rose would be constructed. The application of wind rose is important in many areas such as air dispersion modeling and air quality monitoring (Chammi Reddy and K.J, 2016). According to Muhammad Hisyam et al. (2016), in Malaysia, the four seasons namely northeast monsoon, southwest monsoon and two shorter periods of the inter-monsoon season are applied in expressing the wind rose. The southwest monsoon is between mid-May to September while the northeast monsoon occurs between November to March. The first inter-monsoon is in April until mid-May while the second inter-monsoon occurs in October.

To get a better understanding of the characteristics of wind speed and direction at a particular location, wind rose is the best. The data used such as wind speed and wind direction will be displayed in graphical form to be more stable and function of direction (Droppo et al., 2008). There are several types of data pre-processing that can be used to analyse wind speed and wind direction such as CALMET is a meteorological model of the CALPUFF dispersion model that is constructed for 3D wind (Pezzoli et al., 2014). The investigation of Roubeyrie et al. (2018) use the tool Matplotlib to present the distribution of the wind direction and wind speed in the form of a polar rose plot. Other than that, the WindRose PRO, a Windows application, also provides analyzing and plotting directional variables to represent wind rose with a large quantity of data that can be summarized.

WRPLOT view software application that performs wind rose statistics and wind rose graphic plots. WRPLOT can find the optimum runway orientation by collecting wind data (Abdalla et al., 2013). The user who used WRPLOT has the option to choose the number of sectors such as 16 sectors or 36 sectors to plot. Therefore, it also avoids especially directional bias in configuration modelling analysis (Droppo et al., 2008). The meteorological raw data at the site is collected in Microsoft Excel format and will be converted to SAM file extension before undergoing processing in WRPLOT (Muhammad Hisyam et al., 2016). The wind rose diagram can be exported to Google Earth to get a forecast of possible pollution sources and it shows air movement from

selected points (Azizi et al., 2021) the WRPLOT is an easily visualize and very quickly forms the output, summarizes large wind data with producing quality assurance such as wind class frequency distribution graphs, frequency distribution tables, and wind rose plot (Muhammad Hisyam et al., 2016). Figure 2.3 shows the WRPLOT View provides visual wind rose plots using the meteorological data in fully operational wind rose.

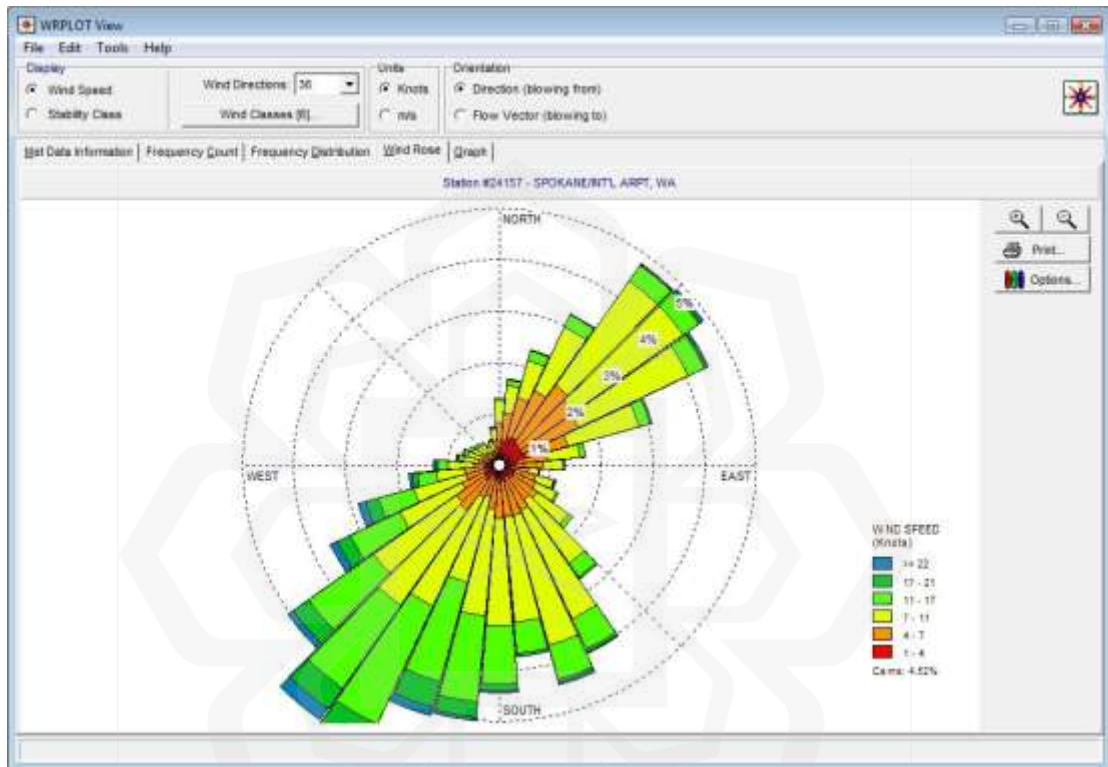


Figure 2.3 Example of WRPLOT View is an analyse of the meteorological data in a fully operational wind rose. (Jesse et al., 2016)

2.8 APPLICATION OF R STUDIO SOFTWARE MODELLING

Quantitative analyses in environmental studies have gloomed and many researchers use it all over the world to verify and predict their research objectives. R studio is one of quantitative analysis. Rstudio.com stated that R Studio is an integrated environment (IDE) for R. Not just other software, R studio is free to download and available in open source and commercial editions. Like other software, R Studio is a cross-platform where it can run on the desktop such as Linux, Windows and Mac (Wong, 2019). R studio doesn't retain any test done on that program as this would be a common development

practice for R programmers. However, for graphical display, it becomes more fun with more testing done and more visually appealing the output tested. R studio is a text-based structure where commands are straightforward, and it can view the reproductivity and transparency of underlying command facilities (Shannon et al., 2020). Carslaw and Ropkins (2012) agree that core features in R such as statistical data analysis, visualization, and high-quality graphic presentation make the R an ideal system to work with. Other than that the R has a package system that contains 2500 available packages for a wide series of analyses known as the Comprehensive R Archive Network (CRAN). R studio offers smooth integration with several tools applied in interactive documentation and provides several features that make it more efficient in writing and debugging code (Shannon et al., 2020).

There are many types of polar series such as polar stripe, polar line, polar area and polar point. According to Carslaw et al. (2013), the bivariate polar plot in R studio is the best method to show the characterization and source detection by providing an effective graph of joining wind direction and wind speed with air pollution concentration. Dai et al. (2022) proved that bivariate polar plots is one of the innovative data analysis techniques that is extremely valuable in understanding the source of pollution and allowing the identification of source contribution using relatively simple information. The study by Kanchanasuta et al. (2020) observed that air pollutant potential sources in various places can be located using observed air quality data such as wind direction and wind speed. Using the pair-wise statistic, two different pollutants can be compared and combined in the bivariate polar plot where the implementation of pair-wise statistics includes slopes from the two linear regression methods and the weighted Pearson correlation method (Grange et al., 2016). The R studio have wonderful programming where it can analyse seasonal trends for four seasons R is easy to use and flexible in data management as it has fewer issues in ad hoc data input. The open-air function is consistent with the format of the data. However, some users mention that the function of the graphical user interface (GUI) is not available in the R package. (Carslaw and Ropkins, 2012). The data on PM_{2.5} in R studio needs to be collected in situ where direct reading will be obtained on the current existing emission at the site (Putri Shazlia et al., 2020).

Figure 2.4 shows example of Rstudio is an Integrated Development Environment (IDE) that contains a manageable and controlled workspace and history, syntax highlighting of text editor, several tools for exporting images and plotting and packages and viewing html/ pdf files created within R Studio (Duarte et al., 2018)

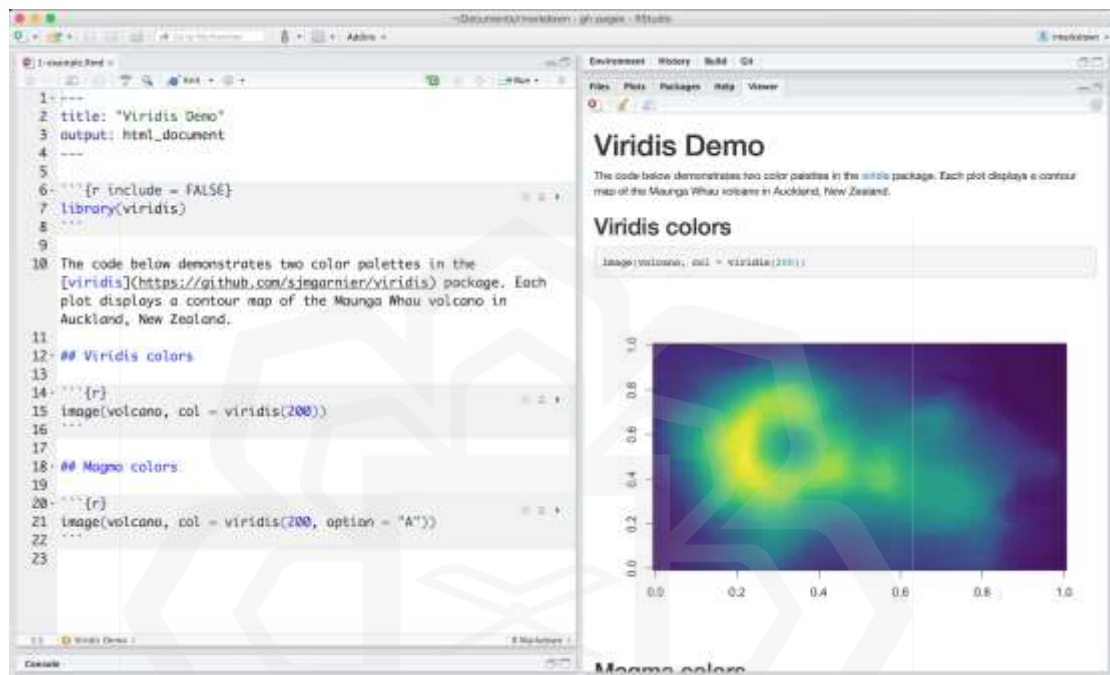


Figure 2.4 Example of the R Studio Graphical User Interface (GUI) to process data and present output of analysis. (Carslaw et al., 2012)

2.9 PM POLLUTION IN ASIA REGION CASES

The global air pollution database released in Geneva by the World Health Organization (WHO) reveals that India has 14 out of the 15 in terms of $PM_{2.5}$ concentration most polluted cities in the world (TNN, 2018). Between the years 2010 and 2014, the pollution level improved but in the year 2015 the pollution level in Delhi started to deteriorate (WHO, 2016) and in the year 2016, Delhi had the highest pollution with an annual average of $143 \mu g/m^3$ more than three times the national safe standard (WHO, 2016). Investigation by Mohammed Sahbaz et al. (2024) state that in 2023, India's construction sector is estimated to account for approximately 13% of the country's economy, whereas, in Delhi, the construction sector contributes 8.4% of $PM_{2.5}$ and 20.8% of PM_{10} emissions. In another study by Guttikunda et al. (2019), transport is a

huge sector that causes critical emission sources due to the country's largest vehicle stock. However, Chen et al. (2020) demonstrated that transboundary air pollution from neighbouring states and emissions from local transport contributed dominantly to the concentration of O_3 and $PM_{2.5}$.

The people in Chang Mai have been exposed to air pollution for about 10 years inhaling particulate matter every day from smog (Nation, 2019). The $PM_{2.5}$ dust particulates, soar in the air can cause stroke, lung cancer, heart disease and lung inflammation if exposed for a long period. It also can shorten people's lives (Nation, 2019). Power plants, biomass burning, traffic and industry are the main emission $PM_{2.5}$ contributors in Thailand (Vongmahadlek et al., 2009). 17% of people in Thailand are affected with lung cancer and 40,000 are estimated annually to cause mortality (Pinichka et al., 2017).

South Asia is facing high levels of air pollutants in most Asia developing countries which describes Sri Lanka, Bangladesh, Pakistan, and Nepal pose several sustainability and environmental health challenges (Abdul et al., 2019). Most of the major metropolitan cities such as Patna Ahmedabad and Delhi violate the $PM_{2.5}$ annual mean national ambient air quality standard (NAAQS) of India and WHO with a higher level than $100 \mu g/m^3$ (Arideep et al., 2017). North India traffic is the major cause of $PM_{2.5}$ level in India but other reasons such as huge population, poor road conditions and unplanned development contribute to higher emission of particulate matter (CPCB, 2013).

Beijing is the world's most populated national capital city, facing a tremendous daily averaged $PM_{2.5}$ concentration exceeding the CAAQS Grade 1 & II standard with $15 \mu g/m^3$ and $35 \mu g/m^3$ (Hao Guo et al., 2017). Meanwhile, Tianjin, both urban and suburban noted that the $PM_{2.5}$ concentration is almost 13 times the WHO annual mean standard (Li et al., 2012). The different issues shared by China, according to research by Li et al. (2017), PM_{10} is the major pollutant in China due to rapid economic development and accelerated urbanization. Strong statement engaged by Zheng et al. (2018) and Gui et al. (2019) stated highest annual $PM_{2.5}$ concentration value of more than $80 \mu g/m^3$ occurs in Southern Hebei as these areas are rapid economic development,

heavily industrial, high industrial activities and densely populated. Research by the Health Effects Institute (2017) stated that long-term exposure to ambient PM_{2.5} had caused 1.1 million deaths in China, supporting studies by Zhao et al. (2020) China also has a great impact on social economy and climate.

About 90% of black carbon aerosol is present in the form of PM_{2.5} due to industrial emissions the main source of pollution (Stone et al., 2010). Years 2008-2009, in Karachi, Pakistan the PM_{2.5} concentration varying 30 µg/m³ and 279 µg/m³ with an annual mean is 101 µg/m³ (Khwaja et al., 2015). The PM_{2.5} in Jeddah, Saudi Arabia concentration ranges between 23.0 µg/m³ and 186 µg/m³ with an average of 74.2 µg/m³ (Hussain et al., 2014). According to Sabir *et al.* (2024) during the winter of 2022-2023 in urban regions, Islamabad, Pakistan experienced a rise in air pollution emissions driven by industrial and economic expansion where PM_{2.5} reached 133.39 µg/m³ above the guidelines of World Health Organization (WHO). Through studied done by Shirmohammadi et al. (2017) about 22,600 fatalities, and 70 million people 40% of children suffering from respiratory diseases where the level of PM_{2.5} is three times higher than WHO guidelines.

Singapore showed a lower PM_{2.5} level with an annual mean of 27.2 µg/m³ and the PM_{2.5} only exceeded 30.0% times where the mean level was 2.70 times higher than the WHO annual mean Standard (Balasubramanian et al. 2003). According to the World Air Quality Report (2020), about 33.8% of cities in East Asia met the WHO PM_{2.5} target in 2020, 10.8% of regional cities in Southeast Asia met the WHO PM_{2.5} target in 2020, 1.6% of regional countries in Central & South Asia met the WHO PM_{2.5} target in 2020 (IQAir, 2020).

From the case literature review, all countries experience the same air pollution problem, which is particulate matter. This is due to some of the stationary sources or mobile sources. In addition, the development that is the demand of the people of the world causes a lot of land to be cleared and forests to be cut down to make way for the development of the people. The concentration value of particulate matter also increases with the emission of smoke from vehicles, especially in cities with high population density.

2.10 CONCLUSION

Many seminars and conferences about the effects of $PM_{2.5}$ and PM_{10} are discussed, and strong arguments occur at national and international levels. Various countries work on numerous policies and standards to maintain air quality in their respective countries. However, efforts to achieve uniformity in air quality standards in every country are quite difficult to achieve because each country has its hidden agenda in reaching a consensus. Through various studies conducted, $PM_{2.5}$ shows parameters that are most dangerous to pollutants as it penetrates the lung barrier and enters the bloodstream. This statement is supported by the World Health Organization (WHO) in its guidelines on ambient (outdoor) air pollution levels.

The exposure of $PM_{2.5}$ to a person should be reduced by reducing the source of the emission and the use of air quality monitoring technology should be held to curb the excessive emission of $PM_{2.5}$. $PM_{2.5}$ is a pollutant that needs to be reduced in our atmosphere and it should be monitored closely. Many researchers carried out the analysis and monitoring process of $PM_{2.5}$ and research on the adverse effects of the pollution of $PM_{2.5}$. But how far do the analysis and monitoring contribute to positive status if many more producers still violate the regulation and standard limit, the concentration of $PM_{2.5}$ increases every day as many activities take part and the countries continue developing without following the developing requirement plan.

Each country develops air quality standards according to the level of research by government agencies and several research centres. Through several studies, the standard development produced will vary by country depending on several factors such as political factors, technical and economic capabilities, and the country's environmental policy. In some cases, the difference in standards will cause a country to allow emissions to exceed the limits set in other countries. The emissions that exceed other countries limit will cause an increase in the number of pollutants in our atmosphere. Uniformity of air quality standards at the international level should be held to curb the release of lingering air pollutants and help in the minimum possible release.

The use of software in analyzing meteorological data is very helpful in making predictions or forecasts for future planning and development. There are many software options, some are freeware and some have to be purchased but it is important that the software can help improve understanding of the spreading of pollutants in our air. Many countries use this software to study the spread of pollutants in the air quality in their country. The use of environmental software must be in line with the current of modernity that is suitable for analysis data that will be used to produce outcomes that are able to help the country's development planning



CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter represents the conceptual framework and methodology proposed in the research. The conceptual framework flow has a relationship with each corresponding phase to form various statistical and graphical results. The relationship in this research is quite a huge range where there is a certain factor that can be controlled by humans and other factors are uncontrolled by the environment. Wind direction, wind speed, and human error are example variables that can be controlled in the study. For instance, the most variable of all weather elements is the wind (Burt, 2012) where the wind speed within a few seconds could be half or double. The wind direction can make numerous turns around the compass by changing 180 degrees within a minute or an hour or two. The methodology in this chapter is quantitative approached and involves several environmental software approaches for better understanding and presenting the data result. The relationship of environmental software used in the study will determine the qualitative result.

3.2 CONCEPTUAL FRAMEWORK

The conceptual framework shown in Figure 3.1 illustrates the three phases of activities that will be carried out during the research. All phases have a different approach of methodology and method. However, every phase has a relationship with each other phase to produce the outcome of the result. The first phase is known as the defined study where the research will consist of idea and problem, a literature review, an objective, and planning. The idea of the research must be aligned with the investigation of the problem to be carried out. This is the most important part where why the study needs to comply with the objectives and find the root cause of the pollution. The research of this study is in lined with the National Policy on the Environment (NEP) Malaysia under

the continuous improvement of the quality of the environment and human life while pursuing economic growth and human development objectives.

After defining the idea and problem of the research, the literature review from other researchers will be cited to give an overview of the study. The literature review from other researchers supports the pillar of the research study with the current knowledge of methodology and the theory of a particular topic. The information on the particular subject area should be discussed within a certain period. It is important to clarify the objective of the research as it is a “steering wheel” in an accomplishment to achieve the focus of research and planning in a comprehensive way of the process. This will help in reducing time planning, shortening the unnecessary pathways, and also controlling the cost of implementation and application in research.

The second phase is the ‘execute’ the flow of the way the research is to be carried out. In this phase, the research will be focusing on the physical component of PM_{2.5}. The physical analysis will be done at site selection to collect the data for analysis. No chemical or biological laboratory activity is involved or takes place in this study. The collection of PM_{2.5} data will be collected at the construction site using the air quality equipment that will be placed at the site. Other than that, on-site observation will be carried out during the period of research to observe and discover the activities' source of emission produced at the construction site. The collected data will undergo statistical modeling software to predict the pattern distribution of PM_{2.5}.

The third phase is the ‘evaluation’ where all the data including PM_{2.5} and the meteorological data will be analyzed together in the environmental modeling software. The environmental modeling software produces maps of the pattern distribution and helps the research findings unravel the complex relationship between the source of emission and the pattern distribution. The conclusion from the analysis will give the opinion and decision of the summary process result of the research. The recommendation from the research study will be suggested at the end of the chapter for improvement the implementation of activities at the construction site.

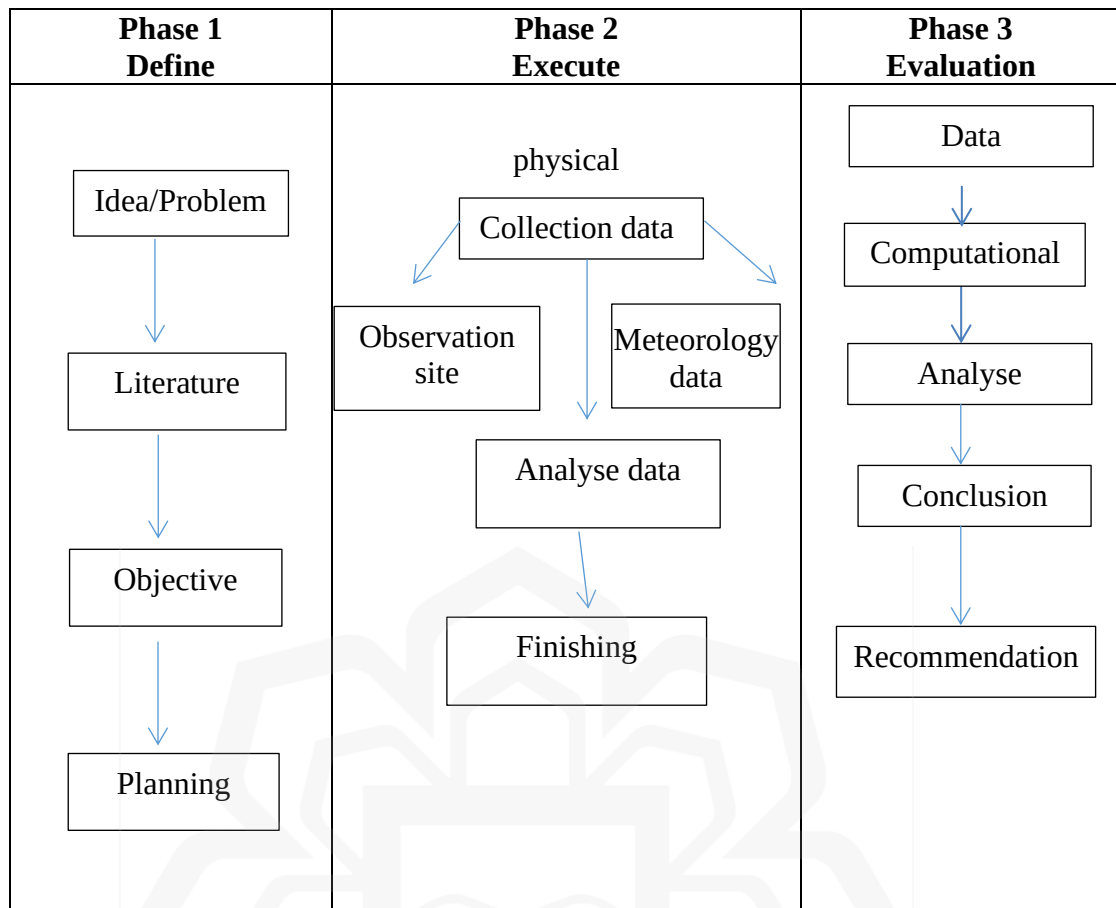


Figure 3.1 Information in the conceptual framework to be implemented in the research study.

3.3 METHODOLOGY FRAMEWORK

Through the implementation of the research study, the methodology of collecting, analyzing the data with the correct software and reporting the facts of PM_{2.5} must be consistent and reliable throughout the research process. The emission of PM_{2.5} at the construction site inconsistently occurs depending on the current activity that happens at the project phase, project schedule implementation, the time frame of activity carried out (several days, weeks, or months) and the influence of meteorology conditions at the construction site.

The emission of PM_{2.5} comes from three (3) major activities at the construction site: site clearing, using vehicles and machinery, and during the construction period. The emissions of PM_{2.5} should not be ignored by the developer as it can cause health

effects to the worker and the environment surrounding. People living near the construction site may experience particulate matter or dust polluting their clothes, windows, and belongings. This can be short or long exposure depending on the period of construction itself. Cough, shortness of breath, and sneezing are the symptoms to occur in a person who is exposed to the presence of particulate matter. Controlling the presence of particulate matter in the atmosphere is impossible as it travels in the atmosphere from one place to another with the support of wind direction and wind speed.

Refer to the Figure 3.2 methodology framework of the research implementation at the construction site. The particulate matter is emitted from construction activities such as site clearing, Machinery activity and during construction occurred. These particulate matters are airborne and move in the atmosphere by an agent of wind. Particulate matter data will be collected using the Aeroqual 500 that is placed at the construction site. The particulate matter will be collected for 24 hours at the construction site. The Aeroqual 500 is a portable air quality handheld portable to monitor air quality in any location and surroundings. This equipment can measure up to 30 pollutants such as ozone, SO_x, NO_x, particulate matter etc. using a sensor. The sensors are housed within interchangeable cartridges that attach to the single monitor base. The Aeroqual is suitable for use in projects, including either to be use as personal exposure monitoring, wide area air quality surveys or short-term fixed monitoring.

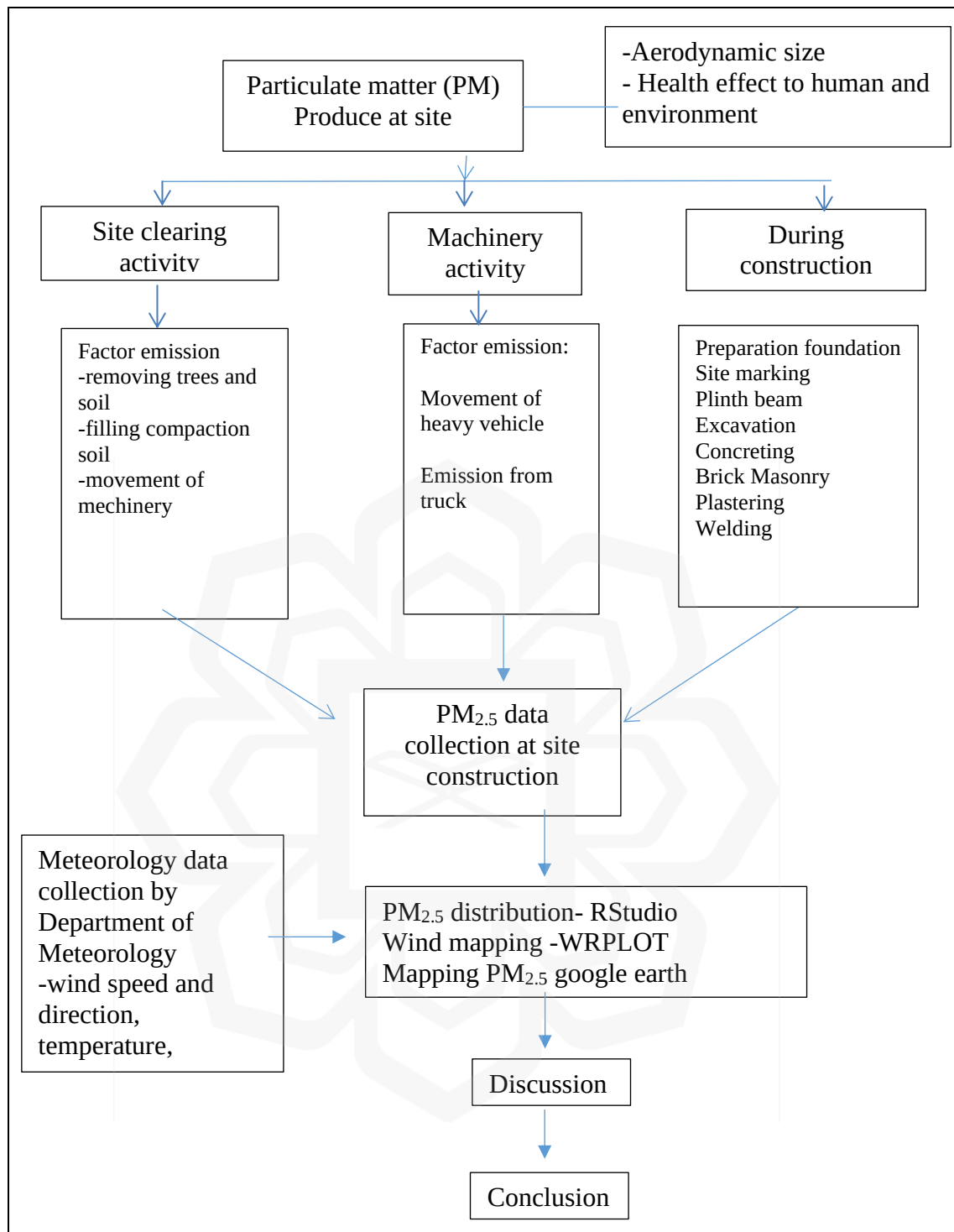


Figure 3.2 Flow Chart of Methodology Process.

The wind direction, wind speed, temperature, rainfall distribution and humidity data were obtained from the Meteorological Department. The meteorological data will be analysed using the WRPLOT Software. WRPLOT is a wind rose program and it is an easy application to work with meteorological data formats where the data is imported from an Excel spreadsheet and can be exported the result to Google Earth or printed for a documentation report. WRPLOT is a free program, and it was originally developed by Lakes Environmental Software Inc. for meteorological data, WRPLOT provides plots and frequent analysis to present the output.

The particulate matter and all the meteorological data will then be analyzed using the R Studio software to determine the pattern distribution of particulate matter. R studio is an integrated development environment for R, where a programming language is used to perform statistical computing and graphics for the output. The tabular datasets of PM_{2.5} are analyzed using the software R within the R studio interface. The R studio can analyze almost all the environmental data such as water, air quality, temperature, precipitation, soil disturbance, fumes, and any other environmental tabular dataset. In R studio there are hundreds of plots, charts, diagrams, graphics, and figures that can be illustrated as output. Data output from the R Studio is then layered data on top the Google Maps.

The discussion is to describe and interpret the significance of the research process in finding a relationship to the research problem that is being investigated. The way of research questions must be connected to the introduction and the literature review which make it easy to explain the understanding of the research problem and contribute knowledge to change that can be informed by practical or theoretical change.

The conclusion is the part where the decision, argument, and judgment to draw the summary after careful thought in the discussion have been made. It is important to raise the final say on the issues and demonstrate the idea subjected to the research problem. In conclusion, it is not subject to niche, but it pushes beyond the boundaries of the prompt by considering broader issues and elaborating on the significance of the findings. The presentation of the conclusion may help other people to see your research in a different way and the implication of change in life could happen in some way.

3.4 MATERIAL AND METHOD

Material and method are an area where it forms the spine of the research. The determination of the material applied and function in this research assist in producing research output as required and achieve the research objective by providing the best results. Implementing the method that use of effective methods and accurate strategies meets the objectives and achieves maximum results in overcoming the problems in this study.

3.4.1 Description of Research Site

The project site is a leasehold land held under PN 25656, Lot 8094, Mukim Penor, Daerah Kuantan, Negeri Pahang measuring an area of approximately 814 acres (Figure 3.3). Yayasan Pahang is the landowner and O&C Properties (Kuantan) Sdn. Bhd (OCPK) is the developer. YP & OCPK have agreed to develop 100 acres of the land into a mixed development which includes commercial development and an affordable housing scheme known as the “Priya Scheme” on a joint-venture basis.

The intended project is named as “PRIYA Scheme” and will comprise 979 units of terrace houses with a floor plan of 20’x 70’, 18 units of semi-detach houses with a floor plan of 40’x 90’, 112 units of semi-detach houses with a floor plan of 40’x 80’ and 41 units of shop lot office. The estimated gross development value of the project are estimated to be RM166 million. The developed area is 161,975 m² and the undeveloped area is 271,382 m². According to the developer, the Priya Kuantan will contain recreational activities such as jogging tracks, a football field, and a playground for the future Priya communities. Selecting Priya Kuantan as a research study, where it is a mixed development project, located within the Kuantan area and it fulfil the requirement of this scoping study. The location is easily accessible from the highway and progress construction is fast and meets the time frame of construction. The surrounding location of the study area consists of sensitive receptors that meet to secure its health and safety. The village area and farming area are the sensitive receptor which needs to be emphasized in ensuring their health and safety are not being violated during construction.

3.4.2 Topography of Research Area

The research area is flat and located on Lot 8094, Mukim Penor, Daerah Kuantan, Pahang Darul Makmur. It is approximately geo-referenced at latitude 3° 41' 19.11" N and longitude 103° 17' 30.29" E. The natural vegetation before construction was an oil palm plantation owned by YP Plantation. The surrounding area consists of peat soil, shrubs small trees. The land use was converted into a mixed development. The elevation of the study area is situated on peat soil with a ground elevation of 7m to 11m above mean sea level shown in Figure 3.4. The distance between the research area and the nearby beaches is about 5.66 km. For the full picture of the topography, see **Appendix A**

3.4.3 Existing Land Use

Adjacent to the research site is the Rumah Kanak-Kanak Sultanah Hajjah Kalsom (RKKSHK) a children's home of a government organization under the Department of Social Welfare, Ministry of Women, Family and Community Development. The RKKSHK is a place for safety protection and cares for children under Section 54 of the Child Act 2001. The RKKSHK is situated on the north side of the research site. For the full picture of existing land use and topography, see Appendix A.

Rumah Kanak-Kanak Sultanah Hajjah Kalsom is a Safe Place institution for the care and protection of children established or designated under section 54 (safe place) of the Children's Act 2001. The objective of RKKSHK is to provide substitute care for children in addition to promoting healthy emotional, physical and mental growth and development in a harmonious family atmosphere by providing daily activities that facilitate them to interact well.



Figure 3.3 The location of PRIYA Kuantan housing area.

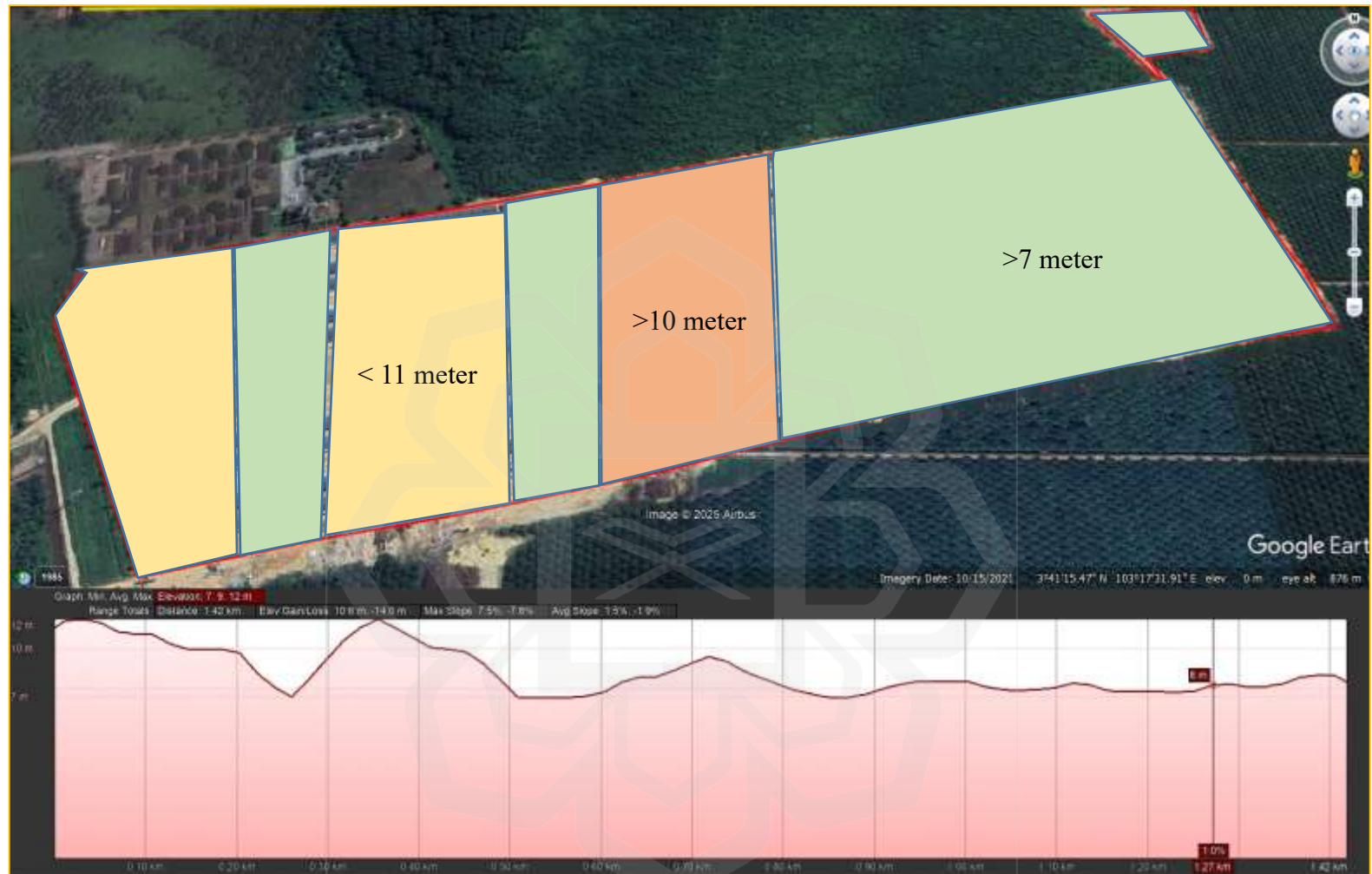


Figure 3.4 The location of the sampling point and elevation of the research area within 7m to 11m above sea level.

About 514 m northern side of the research site, located the Penor Prison Complex under the Malaysian Prison Department, Ministry of Home Affairs. The Penor Prison Complex consists of modern staff housing, a mosque, a prison, and staff infrastructure. While at the southern, western, and eastern boundaries are palm oil plantations, shrubs, other secondary vegetation and residential areas. Most of the surrounding area is palm oil plantation planted. The suitability of organic peat soil and wet condition makes the oil palm plantation the best choice to plant there. Below is Table 3.1 showing the list of detailed settlements within a 5 km radius of the research site. The settlements consist of residential, government, children's safe place institutions, plantation, and several villages.

Table 3.1 List of settlements within a 5 km radius.

Distance from research area (km radius)	Area
1 km	Rumah Kanak-Kanak Sultanah Hajjah Kalsom DOE Observation Tower
2 km	Penor Prison Complex
3 km	Kg. Sri Melati Kg Soi Asnaf MUIP Complex, Majlis Islam dan Adat resam Melayu Pahang
4 km	Kg Soi Kg Baharu
5 km	Sekolah Kebangsaan Melati Perkampungan Sg Soi Jaya Taman Inderapura Jaya Perkampungan Kg Ketapang Perumahan Taman Sg Soi Jaya 2 Bandar Baru Putri Kuantan Perumahan Taman LKPP Ujana

Figure 3.5 shows the radius level of the settlement surrounding the Priya construction site and its surrounding area. The radius level consists of 1 to 5 kilometers. Each level radius is presented in a different colour. While, Table 3.2 shows the ring colour of the circle representing the per kilometer from the research site. The difference between the 2 rings is 1 kilometer. Among the ring, there are sensitive receptors that will be affected by this study. Sensitive receptors may be residential areas, small factories, public authorities, schools, residential areas, industrial estates or agricultural land. Effects such as dust can spread in this area due to wind speed and wind direction.

Table 3.2 The ring colour and kilometer.

Ring Colour	Kilometres
Red	1 km
Green	2 km
Yellow	3 km
Purple	4 km
Grey	5 km

The distance between the site monitoring station and the DOE continues monitoring air quality station (CAQMS) is about 14.5 km (Figure 3.6). The CAQMS is monitored and recorded online for both PM_{2.5} and PM₁₀. The Indera Mahkota is labelled as CA40C station, located in the school compound at SK Indera Mahkota, Kuantan (N 03°49.138. E103°17.817). It is densely populated with highly residential, small, and midsize enterprise (SME) industries, commercial areas, and high road traffic. This station is influenced by motor vehicle emissions, especially early in the morning and late afternoon due to the movement of government staff arriving for work and then leaving work and returning home. All the major air pollutants (PM_{2.5}, PM₁₀, SO₂, NO₂, O₃ and CO) parameter data are recorded on an hourly basis by the Pakar Scieno TW Sdn Bhd on behalf of the Malaysian Department of Environment. The particulate matter concentration was taken from the CA40C station due to its the distance of this air quality station is the closest and most relevant for reference data for air quality monitoring in the study area to be compared.

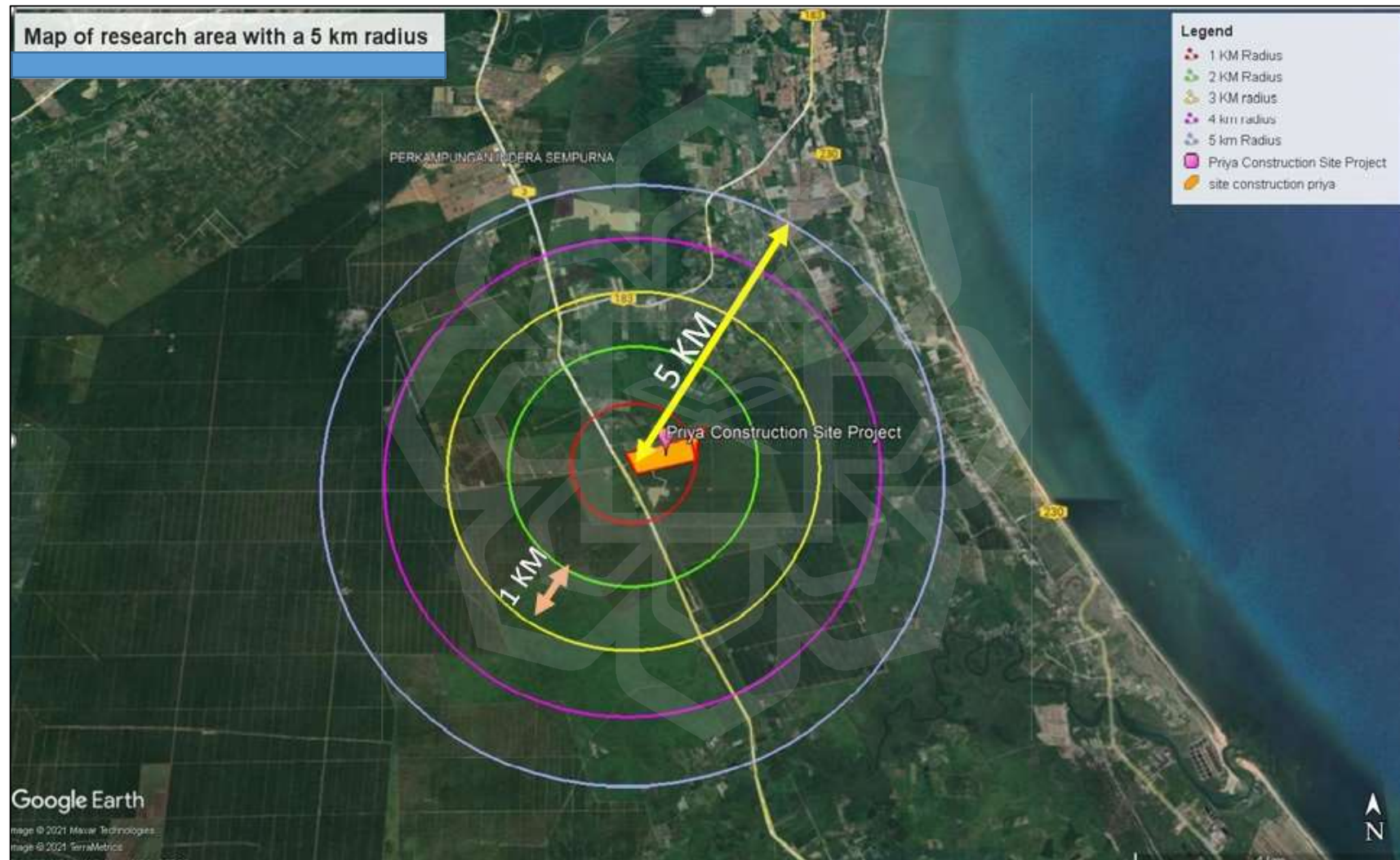


Figure 3.5 The ring level of kilometre of the research area with a 5 km radius.



Figure 3.6 The distance between the DOE monitoring station and the Priya site is 14.5 km.

3.4.4 Socio-Economic Background

According to the Kuantan District Local Plan 2035, the Penur area has a total population of 7,720, which is 1.74% of the population. This is because this area is still an agricultural area and a forest area. The socio-economic background of the population within a 3 km Radius is a farmer, small trader and some working in smallholding palm oil plantations. Other residents are working as government servants, and teachers, working in a private company, and some work in commercial areas within Kuantan cities. Malay is the major ethnic community and minority groups include Chinese, Indian, and others. The plantations that are planted at the site are palm oil plantations and local vegetables such as cucumber, brinjal, choy sum, corn, and chili. Some residents are fishing in Sg. Soi and sell their goods to nearby residents.

3.4.5 Geology Condition

According to the Department of Agriculture (2023), Malaysian peat soil is defined as soil that has a Soil Organic Matter (SOM) content of more than 65% and a thickness of more than 50 cm within the 100 cm depth limit of the soil control section. The general geology of the research site is a peatland area known as the Pahang River North Peatland. According to Rancangan Tempatan Daerah Pekan, has a peatland area of 44,148 hectares, corresponding to 23.58%. This peatland is a land that is prone to peat fires in during dry and hot weather.

The properties of Penor peat are Natural moisture content m (741%), Liquid limit w_l , (243%), specific gravity, G_s (1.32), pH test (4.2), organic content (84%) and fibre content (27.3%) (Adnan Zainor Abidin and Habib Musa, 2018). The observation tower and tube well were located on both sides of the entrance road to Priya construction. The observation tower with 25 meter high and was managed by the Department of Environment and Drainage and Irrigation Department. Figure 3.7 shows the observation tower that was used to monitor and detect any peat or branches of fire that may occur in the surroundings. The Tube was managed by the Department of Geology and Minerals where the tube well was functioning in curbing the incidence of peat or branch fires.



Figure 3.3 Observation tower and tube well.

3.4.6 Meteorological Condition

The meteorology data was obtained from the Malaysian Meteorology Department, Ministry of Environment and Water, specific data collection in Kuantan Meteorology Station for 6 months from 1st June 2020 to 30th November 2020. In 2020, Malaysia was experiencing a COVID-19 epidemic where the government restricted travelling and industrial processes to operate. The research area was closed during COVID-19 and only allowed to be operated by government instruction. Due to this Covid 19, the research can only be carried out for 6 months.

The meteorological data obtained are daily for 24 hours. The data of rainfall, wind speed, and wind direction are obtained in the form of hourly. The data were requested and bought from the Malaysian Meteorology Department where the process proceeding takes five (5) working days to process. Data from the meteorological

department needs to be processed before entering WRPLOT software analysis and R studio.

3.4.7 Current Situation at Site

The Priya construction entrance is just about 200 meters from the Kuantan-Pekan Highway. Figure 3.8 and Figure 3.9 shows the entrance road to the construction site. Every day people use the Kuantan-Pekan Highway to travel from Kuantan to Pekan to transport their goods and services. This highway is quite busy during the day as the volume of vehicles passes by the research site. Other people who travel from Pekan to Kuantan use this highway to travel to the north or south of Malaysia. The speed limit for this highway is 90 km/h. At night, the volume of vehicles may be less or more depending on the users of the roads.



Figure 3.8 Entrance to research site from Kuantan -Pekan Highway.

This intersection is where the vehicle from the construction enters the paved road. On sunny days, soil dust will be produced by the movement of the vehicles but on rainy days the unpaved road will be covered with mud. It is dangerous when driving mud on the tyre on the public road and it becomes a nuisance to other drivers. However, the project proponent has poured pebbles or crushed gravel into the mud area to reduce the mud problem. Figure 3.11 shows a wash trough was set up before the entrance to the research site. The function of the wash trough is to wash the soil or mud that is attached to the tyre and to keep the public road clean from the dirt from the construction area. The purpose of the wash trough is not restricted to sediment control but also reduces dust pollution and seed control.

Figure 3.10 shows the temporary road for contractors, project proponents and the transportation of construction goods. This temporary road is maintained by the project proponent until the project is finished. This road maintenance is carried out regularly so that the road condition is always good and facilitates the movement of vehicles in and out.



Figure 3.4 Off-road entrance from Kuantan-Pekan Highway to the research site is accessible.



Figure 3.10 Soil and gravel unpaved road. The temporary road is not unpaved as the project site is still under construction.



Figure 3.11 Wash trough was set up before the entrance to the research site.

The construction site clearing activity at the research site involves earthwork activities such as cutting the trees down, removing tree stumps and roots, removing large rocks and other debris, and leveling the land with a filling soil process to stabilize the soil level and increase leveling from the actual ground level. This is the first phase of construction to clear the area for preparing a new building site and sub-divisions for development. During this earthwork, the amount of cut material must match the fill material in levelling the area. It is a common technique in making ground surfaces. Whenever the earth moves and the soil is disturbed, natural compaction will be weak. The light soil particles will be aerated or fluffed into the atmosphere. The movement of construction machinery during cutting and filling activity such as skid-steer loaders, bulldozers, dump trucks, excavators, backhoes, rollers, and drum roll compactors on the unpaved road during leveling, cutting unwanted slope, filling, and compacting suitable material layer by layer causing the emission of soil particles into the atmosphere. Other than that, during earthwork cascading drains and interceptors will also be constructed to capture groundwater from flowing downhill onto adjacent areas. Figure 3.12 shows the leveling and compaction of the soil to prepare for development. The leveling will cause soil dust to emit into the atmosphere and cause nose irritation that may lead to inflammation of the mucous membrane when exposed to soil dust.

The particulate matter may be emitted from three different sources of emission that are site clearing activity, machinery activities, and construction activity took place. During the site clearing activity, the scrub tree was removed from the area to clear for the development construction. The land needs to be filled up with soil to level the land to prepare for the base foundation. This activity is known as the 'dumpy level'. At this point, the dump truck unloads the soil at the prepared area. The fine particulate soil will emit into the atmosphere when the dump truck unloads it. It is because the soil on the dump truck is loose and loses its stability strength during unloading. Then, the excavator and the bulldozer started to level the soil and flatten the area until it meets the ground level measurement requirement. The soil compaction using the compactor is used to increase the density of soil and to ensure the soil is performed properly to avoid settlement of the soil occurring. The compaction must meet at least 95% compaction of the maximum density. Compaction helps in reducing the number of air pockets or voids of air that are expelled from the void space in the soil.



Figure 3.12 Levelling and compaction soil at the construction site.

The second source is the machinery movement such as dump trucks, cement mixers, excavators, compactors, bulldozers, motorcycles, and cars at construction sites that contribute to the emission of particulate matter. The dump truck load of sand and soil, cement mixer, trailer, and other vehicles, enter the construction on an unpaved road and emit the particulate matter due to the interaction of vehicle tires with the unpaved road surface. Speeding of vehicles also causes emissions as the vehicles move fast on the unpaved road. The structure of the surface soil of unpaved roads is loose and it is easy to emit into the atmosphere. Due to catching the number of trips and to fulfill the time frame of construction, trucks enter the construction in large numbers at one time. The dust is profusely emitted into the atmosphere and causes a visibility hazard to workers, and it is dangerous to be inhaled by a human.

The trucks should enter the site at a distance between numbers of trucks and trucks should move together in a slow movement to reduce dust emissions. On a rainy

day, the soil (dirt) became mud at the construction site. Most heavy vehicles' tyres are stuck with mud. The mud will pile up on the track and wheel and this causes the spreading of the dirt onto the highway road. The highway will become muddy on rainy days, but the dirt will form lumps of soil and cause a hazard to road users. Figure 3.13 shows the number of trucks and vehicles entering the construction site at one time. The trucks enter the construction at any time from 8 am to 6 pm. The trucks carry loads such as soil, sand, cement and various equipment to be use in construction. The trucks carry more than one load of the trucks, which can damage the strength and structure of the ground when it drives over this road in the rain.



Figure 3.13 The dump tracks enter the construction site.

Figure 3.14 shows the preparation of the raft foundation and superstructure including beams, columns, and slabs that may emit particulate matter. The raft foundation is a continuous slab resting on the soil that extends over the entire footprint of the building. It's transferring its weight to the ground and supporting the building. A

raft foundation is used when the soil is weak and helps to reduce the stress on the soil. The construction of a raft foundation may cause the loss of soil structure on surface soil and emitted into the atmosphere. Constructing superstructures such as frames, roofs, beams, columns, walls, stairs, and others also produces the same problem at the site.



Figure 3.14 The raft foundation and superstructure in progress at the construction site

The particulate matter produced from those activities will be measured and monitored on-site in this research study. The data of $PM_{2.5}$ will be collected at site construction by placing the air monitoring equipment known as Aeroqual 500. Aeroqual 500 is an innovation of portable air monitoring that easily collects and monitors $PM_{2.5}$ data anywhere. While the meteorological data such as wind speed, wind direction, temperature, humidity, and rainfall, were extracted from the Malaysian Meteorological Department using the Kuantan station as data analysis in this research. The meteorological data need to be purchased at the Malaysian Meteorological Department (METMalaysia). The meteorological data will be analyzed using Wind Rose program

software and R studio software. The outcome of the research will be mapped using Google Earth. Google Earth is a computer program that represents the Earth by superimposing satellite images in 3D representation. In mapping the distribution of particulate matter, RStudio can deliver graph and plot presentation. RStudio is an integrated development environment (IDE) for R developed by R Studio PBC founded by JJ Allaire. RStudio has interesting features that include support for authoring Swerve documents executed from source, code completion and searchable history.

3.4.8 Sampling Point of Particulate Matter

The monitoring of particulate matter in the research area was determined at one (1) sampling point as shown in Figure 3.15. The sampling point was determined as one point because the area flat plain area was between 7 meters to 11 meters. No hilly area is determined in the research area. After a discussion with the project manager, Encik Amirul, he suggested that the particulate matter equipment be placed at the post guard after considering the method of monitoring and safety of daily monitoring. The latitude and longitude coordinates of the sampling equipment are 3°41'16.26" N dan 103° 17' 11.13" E.

This Aeroqual device needs to be placed in a standing and high position. In that case, it can easily measure particulate matter concentration and can provide an accurate reading. For this study, the placement of Aeroqual at this point is under the advice of the project manager in the construction area to ensure that the device is not hit by vehicles that often enter the construction area. The area does not have high hills and most of the area is a lowland area. Therefore, the installation of Aeroqual should be constantly monitored to ensure that this tool is working throughout the study.



Figure 3.5 Location of the sampling point at the research site near the post-guarded house after considering the safety of the monitoring period.

The Aeroqual 500 is placed at the entrance of the construction site. (Figure 3.16). The Aeroqual 500 has been in place for 6 months and its continuous monitoring the emission of $PM_{2.5}$. Aeroqual is a very strong brand and is widely used in construction areas to obtain dust or gas emission readings. Among the projects that use Aeroqual such as the Exide Residential Cleanup Vernon project, California, United States America, used Aeroqual to monitor real-time particulate matter at each residential clean up site. The equipment proves to be able to provide collections of data and to alert the exceedances of dust emitted from the activity at the site. Another project such as Alafia Development in Brooklyn, East New York also uses an Aeroqual to monitor the compliance of particulate matter emission from the project site. The application of Aeroqual has brought a timer saver in monitoring the air quality and reduces the huge cost in the project.



Figure 3.6 The Aeroqual 500 and its tripod are used together during the monitoring at the study site.

Figure 3.17 shows the map of the sampling point at the site. The justification for only one sampling at the site is that the area under construction is only 155,566 m³ and the active activities emission sources are near the air sampling point station. The entrance for all vehicles including construction staff cars and trucks is close to the location of the air quality monitoring station.



Figure 3.7 Sampling point station at the site

3.5 EQUIPMENT AND SOFTWARE

Air pollution modelling and monitoring rely on a variety of equipment and software to assess air quality, predict pollutant dispersion, and guide mitigation strategies. The equipment used in this study is the latest equipment and is used by the environmental consulting sector. Therefore, the selection air quality monitoring equipment shall be carried out accordance with the Malaysian Standards MS 1596 or MS 1723 or method published by the U.S Environmental Protection Agency (USEPA) requirements, real-time air quality monitoring and be in accordance with the traditional air quality project. The equipment that been used in the study area is Garmin Ps, and Aeroqual Series 500.

The software for air quality tools can be found in the market and the prices for the equipment and software are affordable. However, air quality equipment should be well taken care of and cleaned every day, especially at the sensor head. This is to avoid errors in reading sensor data. The maintenance of air quality monitoring equipment is not as difficult as it seems but it must be cleaned every day which requires craftsmanship. The software been used in the study are WRPLOT, Rstudio software and Welch's T-test.

3.5.1 Geographic Positional System (GPS)

Garmin GPSMAP 64s Handled Geographic Positional System (GPS) was used to determine the position to place the air quality monitoring equipment at the research site. The GPS is easy to handle and it's portable to use. Figure 3.16 shows a handheld Garmin GPS Map 64s that was used in this research. The GPS is used to get the accurate navigation location of the research area. This mapper has an internal memory of 4GB with a 160x240 pixel resolution to provide clear images in any weather condition. The weight of GPSMAP 64s is 230 grams, compact and incredibly versatile to use in any range of weather conditions. The procedure for determining the coordination is as follows:



Figure 3.8 Garmin 64s consists of a high-sensitivity GPS with features of a 2.6" sunlight-readable colour screen. It can share wirelessly with other compatible devices on routes, geocaches and waypoints.

- i. Using the Global Positioning System (GPS) device to determine the exact coordinate location of placing the Aeroqual 500.
- ii. Mark the location near the post guard of the construction site.
- iii. Find the coordinate location for latitude 3°41'16.26" N and longitude 103° 17' 11.13" E.
- iv. Repeat steps 1-3 for new coordinates.

3.5.2 Aeroqual Series 500 Portable Air Quality Monitor

The PM_{2.5} was measured using the Aeroqual Series 500 that was monitored at the research site for six (6) months. Checking the condition of the equipment and logging data was done daily to make sure the equipment is in good condition. The Aeroqual Series 500 is used in this research as it has included seven (7) bases such as a monitor base, LCD digital display, lithium charger, lithium battery pack (11.1V), the monitor to USB cable, desktop software, build datalogger and tripod. The available sensor is only

particulate matter (PM₁₀ and PM_{2.5}). Other than that, the accessories Aeroqual used are an industrial enclosure for an air quality monitor, a portable supply battery portable monitor carry case and a wall bracket. The portable supply battery must be applied at the site during monitoring as the lithium battery only stands for up to 8 hours. (Aeroqual, 2019). Figure 3.19 show the Aeroqual Series 500 that used in this study.



Figure 3.9 The Aeroqual Series 500 to collect particulate matter data.

3.5.2.1 Installation Aeroqual at Site

In order to prepare the monitor at the site, the following action needs to be done.

- i. The sensor head need to be correctly inserted into the top of the monitor.
- ii. Aeroqual batteries must be fully charged before they are attached to the monitor. The Lithium battery to be charged can be removed from the base or it can be charged directly to the sensor head.
- iii. A large brick or stone is very useful for tying the base of the tripod. It must be tied with a brick to prevent the tripod from falling in strong winds.

- iv. An Aeroqual protection box is provided and installed to house Aeroqual tools to prevent Aeroqual from being exposed to rainwater.
- v. The backup batteries are installed together when monitoring is carried out to support the continued ability to collect air quality data.

3.5.2.2 Sensor Head

The steps are as follows:

- i. The sensor head must be warmed up before use to burn off any contaminants that occur on the sensor.
- ii. It takes 3 minutes to warm up after the monitor is switched on.
- iii. The sensor head must always be placed perpendicular to the airflow to avoid damage to the sensor.
- iv. The sensor head cannot be removed when the monitor is in the 'ON' position, as it will damage the unit.

3.5.2.3 Operation and Set Up the Monitor

A monitor display, also known as a display terminal, is a basic output device in a computer system. Figure 3.20 shows the screen display of Aeroqual Series 500.

- i. Aeroqual is activated by pressing the power button until the screen activates.
- ii. The monitor display will be shown the AEROQUAL MONITOR and series version.
- iii. Switch off the Aeroqual by pressing and hold the power button for 2 seconds until the monitor beeps is sound.

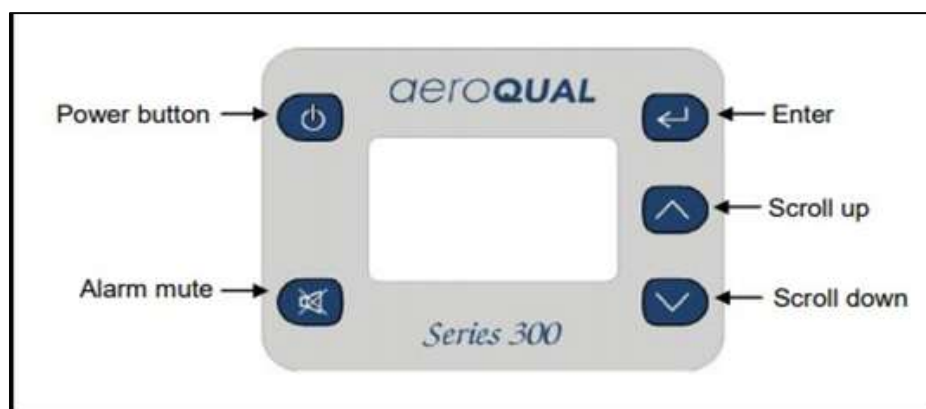


Figure 3.10 Aeroqual front display on the monitor.

3.5.2.4 Menu Function

The menu will appear on the screen as illustrated in Figure. 3.21 The screen will appear several options of choice such as location ID, maximum and minimum AV, calibration, monitor setup, and logging setup. This function menu will make it easier for us to select the activities required before starting the setup for monitoring. It depends on our needs and our choices when using this tool.

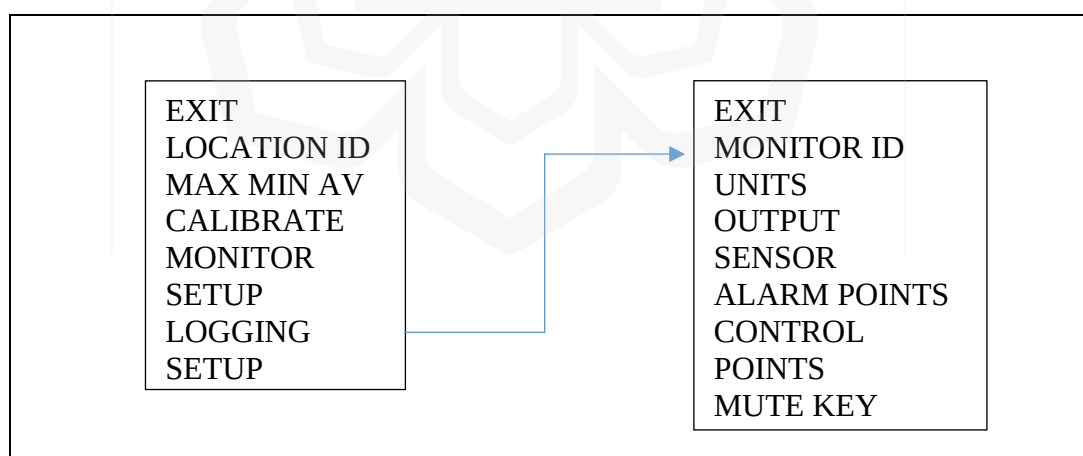


Figure 3.11 Menu display on Aeroqual Series 500.

3.5.2.4.1 Units

The Series 500 monitor can log parameter such as temperature, gas sensor, PM₁₀ and PM_{2.5}.

- i. The selection of 'UNIT' in the LOGGING SETUP under MONITOR SETUP, LOG FREQ 1 MIN will appear on the display. Use the scroll up and down buttons to select the required frequency in 1-minute intervals.
- ii. The button of CLEAR LOG is to clear the logging data in the Aeroqual. It can be chosen either YES or NO to CLEAR LOG.
- iii. The LOGGING is to log the data during real-time monitoring. It can be chosen ON or OFF to log the data. It can also choose either ppm or mg/m³. In this study, the unit ppm (parts per million) is chosen to apply the unit collection.

3.5.2.4.2 Data logging

Up to 8188 data points can be logged by the Aeroqual Series 500. The Logged data will be logged directly to the PC using Aeroqual software.

- i. PC data logging

The USB cable is needed to connected the monitor and PC (File → Start PC data). The data will be logged directly to the database on the PC. No data will be stored on the monitor memory.

- ii. Downloading logged data from Series 500

Data from monitor memory can be download by File → Download Logged Data. However, the situation the logged data does not completed, terminated or stop may due to several reason such as:

- Data has been deleted after downloaded into the PC.
- The monitor is turn off.
- Close the PC software program and switch on the monitor on to continue the downloading process.

3.5.2.5 Calibration of Aeroqual

The calibration of Aeroqual was done in factory calibration. For factory calibration, the sensor head is annually calibrated. The accuracy of factory calibration for the particulate matter sensor head is $\pm 0.005 \text{ mg/m}^3 + 15\%$. The sensor head for particulate matter can't be done on field calibration using Aeroqual's calibration accessory. The sensor head of particulate matter can't be calibrated using Aeroqual's calibration accessory because the sensor head of the particulate matter is Laser Particle Counter (LPC). Most of the field calibrations for sensor heads available are gas calibrations such as carbon monoxide, carbon dioxide, hydrogen, hydrogen sulfide, ozone, sulfur dioxide, methane, non-methane hydrocarbon and VOCs which are not suitable for LPC sensor heads. The LPC field calibration isn't available by the generator for field calibration. Table 3.3 below shows the Aeroqual sensor head specification that was used in the research monitoring.

Table 3.3 The Aeroqual sensor and its head specification

Sensor code	Particulate matter
Resolution	0.001 mg/ ³
Range	0.000 to 1.000 mg/m ³
Sensor type	Laser particle counter
Response time	5 second
Temp	0 to 40°C
Minimum Detection limit	0.001 mg/m ³
Relative humidity	0 to 90% non-condensation

The Aeroqual Series 500 follows the US EPA air quality index values for particulate matter (PM_{2.5}) under the revised Air Quality Standards for particle pollution. The Aeroqual 500 Series has been reviewed and approved by EPA to meet data quality objectives. The EPA has developed several SOPs which not have been formally published but can be used as a guide for the user to adapt them for the projects.

However, in Malaysia, the air quality index is not available specifically for particulate matter such example, unlike the USA EPA. Table 3.4 shows the revised AQI for fine particle pollution from USEPA. The AQI is formed in numbers on a scale from 0 to 500 rather than in concentrations. In Malaysia, the air quality index is in the combination of the parameters such as PM_{2.5} and PM₁₀ with the other 5 gases (S_{ox}, NO_x, CO, CO₂, and Ozone) to produce the Malaysia Air Quality Index.

Table 3.4 Air Quality Index (AQI) for fine particle pollution (PM_{2.5}) from the source of The National Ambient Air Quality Standards for Particle Pollution by the Environmental Protection Agency (EPA, 2017)

AQI Category	Revised Breakpoint (1999 AQI) (µg/m³, 24-hour average)	Revised Breakpoint (µg/m³, 24-hour average)
Good	0.0– 15.0	0.0-12.0
Moderate	> 15.0 -40	12.1 – 35.4
Unhealthy for sensitive group	> 40.0 -65	35.5 -55.4
Unhealthy	> 65.0 -150	55.5 -150.4
Very Unhealthy	> 150 -250	150.5- 250.4
Hazardous	> 250 -350	250.5- 350.4
Hazardous	> 350 -500	350.5- 500

The Aeroqual is very easy to install at any site. The equipment is light and hand-carry making it potable to bring anywhere. The importance that needs to be taken up is that the Aeroqual must be placed in the box with 2 outlets (in and out outlet) to avoid the rain. The sensitive sensor on both sides will damage the equipment if directed to the rain. This equipment belonged to the property of GS Alam Lestari Consultant who approved be use of the equipment for this study. The price of an Aeroqual Series 500 is around RM14,000 per unit.

This is one of the challenges to ensure that the equipment is not damaged and lost throughout the research process. Every day, the equipment was monitored at the site and the equipment was running and collecting data continuously for 6 months. The connection during installing the equipment must be correctly made to avoid mistakes or data redundancy. The daily data collection from the Aeroqual Series 500 will be transferred to software that is installed on the laptop desktop. Extension batteries must always be checked to ensure the Aeroqual Series 500 is functioning every day. If placing the Aeroqual Series 500 at the wrong location it may end up being crushed by a heavy vehicle. The equipment is about 1 meter high and sometimes it can't be seen by the lorry drivers or other heavy vehicles. Therefore, determining the right place is important in engaging the Aeroqual Series 500 for the safety of the equipment. In rainy conditions, it is the biggest challenge is to changing the daily battery in an open area without any shade and also to set up the Aeroqual Series 500 to collect data again.

Figure 3.22 and Figure 3.23 shows the setup of the Aeroqual Series 500 at the construction site. The date and the time should be the exact time. This helps in monitoring the collection of data and avoiding wrong data collection. It is important to check every day as daily performance monitoring for a regular and consistent check on the equipment to ensure the performance equipment works well and is in good condition. The tripod is three-legged to support the equipment. However, the chances of falling down the tripod could happen due to wind. A stable tripod is not an obstacle as the land is flat and not hilly. The selection of the sampling location of the monitoring equipment is very important so that it does not interfere with the monitoring results. Among the things that need to be considered is the type of pollutant that will be studied. For example, pollutant types such as SO_x or NO_x from factory smoke should be placed in monitoring devices close to the source of the final emission in the chimney. For this PM study, it only needs to be installed in an open space. The placement of this monitoring device should be placed in an area that is easy to access and free of interference from animals. If it is placed in an area that is difficult to access then it will complicate the data collection process and it will take a long time to reach the monitoring device. In addition, the sensor of the monitoring device needs to be protected with a cover so that this sensor does not touch the rain and is quickly damaged when exposed to rainwater.



Figure 3.12 Preparing for Installation of the Aeroqual Series 500 at the study site.



Figure 3.13 Checking the equipment before starting the monitoring.

3.6 METEOROLOGICAL DATA ANALYSIS

Meteorological data analysis was important to analyses as to understand the weather condition that affects the performance of construction activities. The weather condition was used to plan the activities at the construction site and reduce the emission of particulate matter. It also helps the project manager in scheduling weekly and monthly activities to achieve the target plan. The limit of visibility during windy and rainy days is to be considered for the safety of the workers and risks of accidents occurring. It is important to watch the weather condition daily as the weather conditions were inconsistent from time to time and may change drastically unconditionally during the project period. The weather condition components such as temperature, humidity, rain and wind speed, and wind direction were the common analyses.

3.6.1 WRPLOT View Software

In this research, the meteorological data were analysed using the WRPLOT View software. WRPLOT View Software is a wind rose program that provides the plot for meteorological data formats and visual systems in rose plots. WRPLOT is registered under licensed Lakes Environmental Software and it is an established wind rose management and navigation. The WRPLOT Software is freeware and available to download on weblakes.com. The software is easy to use and the guidance using the software is easy to follow the instructions. The WRPLOT View software is software version 8.0.2. Figure 3.24 shows the WRPLOT View Software that was used in the research. WRPLOT View Software is a quality assurance software as this software can summarize large amounts of wind data by editing, creating, and updating visual plots in multiple formats.

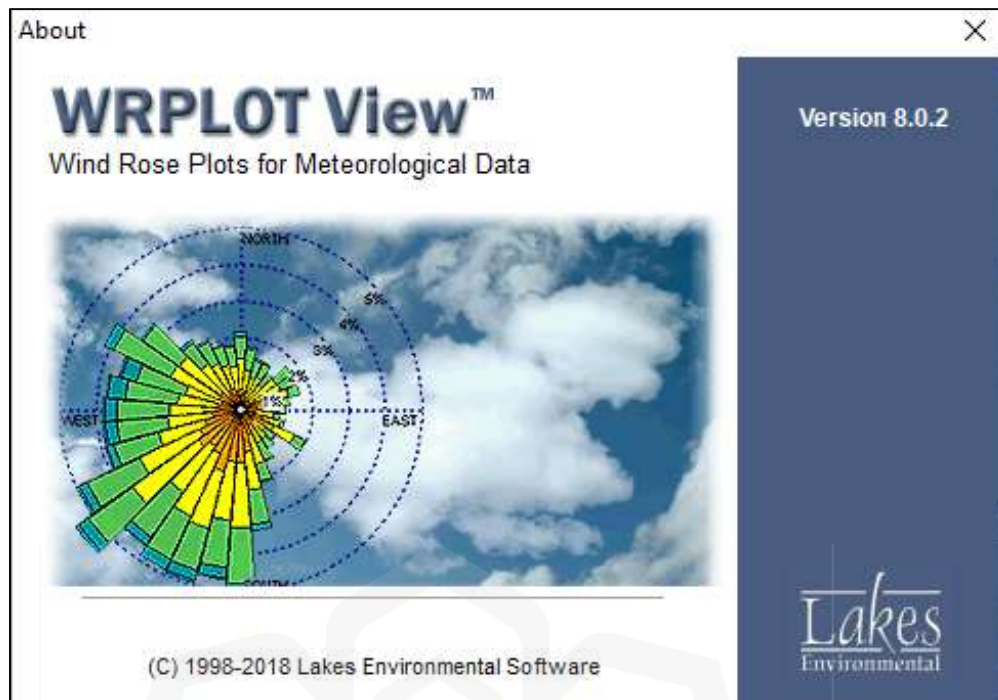


Figure 3.14 The WRPLOT View desktop is easily installed and its freeware (Lakes Environmental,1998-2018)

There are 16 direction sectors (22.5 degrees) and six (6) wind speed classes can be created with understanding wind rose for a given time and location period. The relevant information such as the coordinates of site, unit measurement (knots or meters/second), and orientation of the wind (blowing from or blowing to) must be specified and clearly defined.

The meteorological data from June until November 2020 will be analysed using the WRPLOT software. The WRPOLT software data will provide other information such as Frequency distribution, wind rose pattern and wind rose graph. WRPLOT software is automating the process of calculating wind direction and frequency where it saves times and effort for operator who runs the software. The friendly software can use for various application which provides reliable and accurate result. WRPLOT is easy is use and it is not completed software to handle. With high quality wind rose diagram and various colours, make it easy to interpret and better understanding in form of figure. This software is always updated by Lakes Environment with new features and improvement making it a choice of professional a valuable tool to analyses meteorological data at any time.

Figure 3.25 is the view display of WRPLOT. The meteorological data need to be keyed in according to the column and row as in the meteorological data information tab. The analysis results will be shown in the frequency count tab, the wind rose tab, and the graph. The other information such as the total number of hours, average wind speed, calm record, calms winds frequency and data availability will be calculated by the software. Figure 3.26 shows the meteorological data in an Excel file is imported into the WRPLOT software. Meteorological data can be one-year data or more than one-year data. Monthly meteorological data also can be analysed using this software.

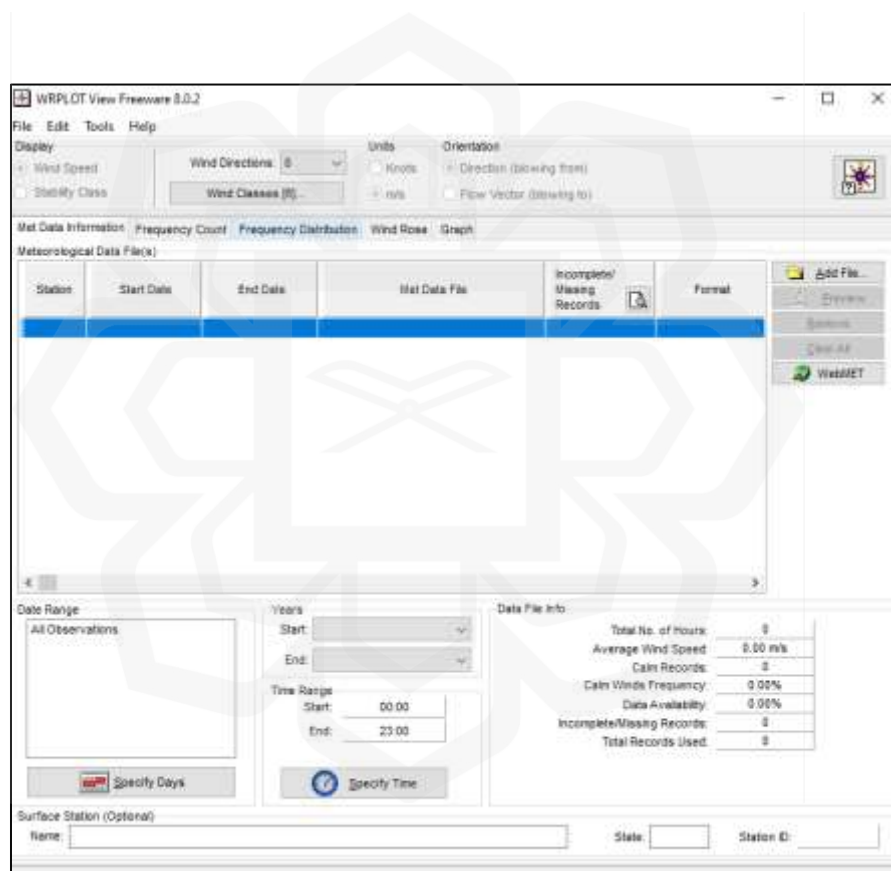


Figure 3.15 The WRPLOT View displays on the desktop
(Lakes Environmental, 1998-2018)

The data meteorological from June to November 2020 from the Malaysian Meteorological Department (MET) such as wind direction, wind speed, and rainfall precipitation (mm) are analysed using this WRPLOT. Most of the meteorological data are in an Excel file. The Excel file can be used directly in WRPLOT. However, in the WRPLOT, the Data Fields column needs to define the information in the Excel file for

import. Example defining the information as follows Figure 3.26. The Excel File in the lower column must follow the information stated in Data Field Name and Excel Column Name in the upper column. The incorrect information keyed in will cause the software not be analyzed. The Data Field Name and Excel Column are shown in Table 3.5.

Table 3.5 Code for meteorological data in Data Field Name and Excel Column Name.

Data Field Name	Excel Column Name
Year	B
Month	C
Day	D
Hour	E
Wind Direction	F
Wind Speed	G
Hourly Precipitation	H

Data Fields
Station Information

#	Data Field Name	Excel Column Name	Missing Indicator in Excel File	Unit in Excel File	Number Type
1	Year	B		N/A	YY, YYYY
2	Month	C		N/A	1 to 12
3	Day	D		N/A	1 to 31
4	Hour	E		01 to 24	00 to 23, 01 to 24

First Row to Import: 1 Set
Last Row to Import: 4395 Set
Import

Excel File SAMSON File

	A	B	C	D	E	F	G	H
1						Mean Surface Wind		Rainfall
2					Hour	Direction	Speed	Amount
3	Stnno	Year	Month	Day	(MST)	(°)	(m/s)	(mm)
4	48657	2020	6	1	1	340	2	0
5	48657	2020	6	1	2	20	1	0
6	48657	2020	6	1	3	360	1	0
7	48657	2020	6	1	4	320	2	0
8	48657	2020	6	1	5	360	1	0
9	48657	2020	6	1	6	20	1	0
10	48657	2020	6	1	7	330	1	0

Figure 3.16 Example of Excel file matching the Data Field Name for a year, month, day, and hourly in WRPLOT.

#	Data Field Name	Excel Column Name	Missing Indicator in Excel File	Unit in Excel File	Number Type
4	Hour	E		01 to 24	00 to 23, 01 to 24
5	Wind Direction	F		degrees	Integer
6	Wind Speed	G		m/s	Decimal
7	Hourly Precipitation	H		hundredths of inches	Integer

First Row to Import: 1 Set Last Row to Import: 4395 Set Import

Excel File SAMSON File

	A	B	C	D	E	F	G	H
1						Mean Surface Wind		Rainfall
2					Hour	Direction	Speed	Amount
3	Stnno	Year	Month	Day	(MST)	(°)	(m/s)	(mm)
4	48657	2020	6	1	1	340	2	0
5	48657	2020	6	1	2	20	1	0
6	48657	2020	6	1	3	360	1	0
7	48657	2020	6	1	4	320	2	0
8	48657	2020	6	1	5	360	1	0

Figure 3.17 Example of the Excel file matching the Data Field Name for wind direction, wind speed and hourly precipitation.

Station ID: 1 City: KUANTAN State: PH

Latitude: 3° 46' 0" N Longitude: 103° 13' 0" E Time Zone: UTC+8 (Beijing)

Station Elevation (MSL) [m]: 15 (Optional) Search Stations...

First Row to Import: 1 Set Last Row to Import: 4395 Set Import

Figure 3.18 Example of information in Station Information required information such as Station ID, City, State, Latitude, Longitude, Time Zone and station Elevation (MSL)(meter)

Figure 3.27 illustrates the Excel file matching the Data Field Name for wind direction, wind speed and hourly precipitation. WRPLOT only analyses the complete data set and follows the formatting of the software. Figure 3.28 show the time zone for Malaysia is 8 hours ahead of Coordinated Universal Time (UTC+08). Malaysia has

uniformly in the beginning and end of day light saving time. Therefore, Malaysia Time applies only to Malaysia and Malaysia Time does not have an associated day light saving time. Figure 3.29 shows the wind rose section. the orientation of the wind rose can be chosen as either Direction (blowing from) or Flow Vector (blowing to). How often the wind direction can be defined through the length of each ‘spoke’ around the circle. The different colours of each spoke present the details of speed in m/s and the calm percentage is the calm condition that represents the size of the center circle where the bigger the circle the higher the frequency of calm conditions.

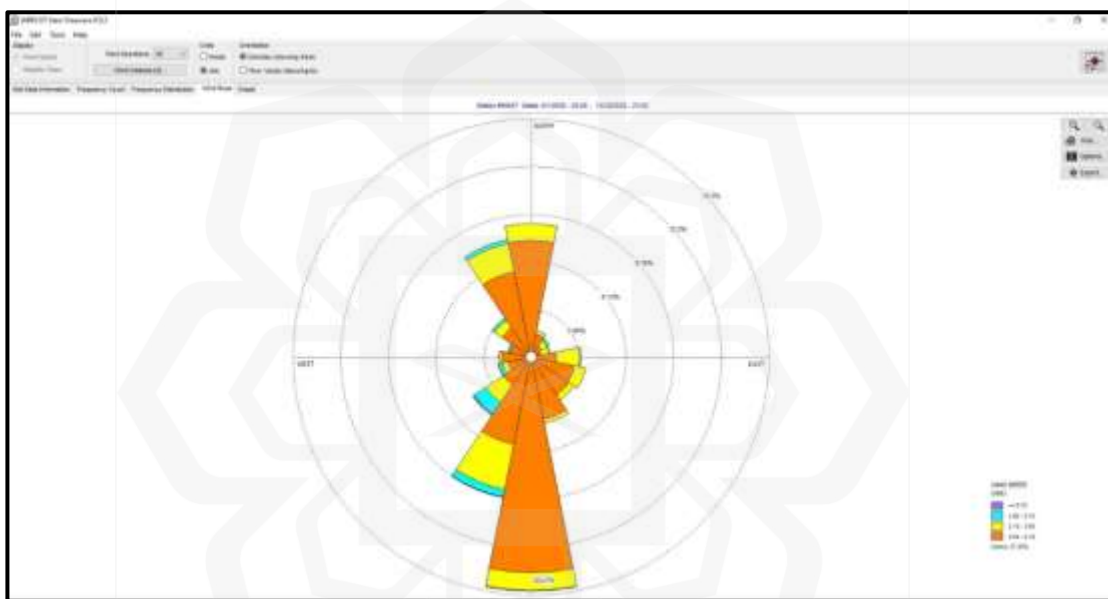


Figure 3.19 Example of the wind rose produced by WRPLOT (Jesse, 2016).

The concentric circles in dashes represent various percentage frequencies of time. The innermost full circle in the wind rose represents the percentage occurrence of calm (wind speed less than or equal to 3.06%), the value that is inscribed within the circle. The innermost radiate various arms. The total percentage frequency of time the wind blows from the direction concerned is shown by the total length of each arm. Each arm in wind rose is subdivided into rectangles and line of different sizes or shades is subdivided into each arm. The key scales at the right below corner represent various classes of speed in m/s. The wind rose was then imported to google earth to map the wind rose. The detailed output will be discussed in chapters 4 and 5 with wind rose petals explanation.

3.7 POLLUTION DISTRIBUTION SOFTWARE

Pollution distribution software is to visualize and designed to model the spread of pollutants in water, air or soil contamination occurred in the environment. These tools has help the environmental scientists, government agencies, and researchers to predict and manage pollution levels and their impact on ecosystems and human health by employs environmental data and complex algorithms to simulate pollutant dispersion based on factors such as topography, weather conditions, water currents and wind patterns. There are many tools of air pollution modelling software such as WindTrax, CALPUFF, AERMOD and etc.

3.7.1 R Studio Software

In this study, an application of RStudio was used in presenting data analysis information of the graph, histogram, and pattern distribution of PM_{2.5}. The R Studio is an integrated development environment (IDE) for R. It is also statistical computing where all the descriptive analysis can be done in this R Studio. R can be downloaded in Linux, Mac OS X, and windows. An R language is easy to use for all users as it includes a console, syntax-highlighting editor that supports direct code execution, as well as tools for plotting, history, debugging, and workspace management. Figure 3.30 showed the panel of R Studio in the desktop display. R is suitable for beginner and advanced power users as it is easy to use and incredibly user-friendly. R is simplifying handling dependencies and package management as the R studio comes with a comprehensive set of tools that relate and play each other to speed up R code and data analytics.

However, the user of R studio must have a solid understanding of R and read many libraries of R. The R is only designed to work for R. The R is restricted as it uses only one programming language and only this programming language can unlock R studio's features. R studio also has another limitation, which is that R studio is unable to handle a very large data set. The R studio can become crash or unresponsive if large data is being read into the software. The data needs to extract insight many times from the big data sets to process by understanding the coding codes and code optimization.

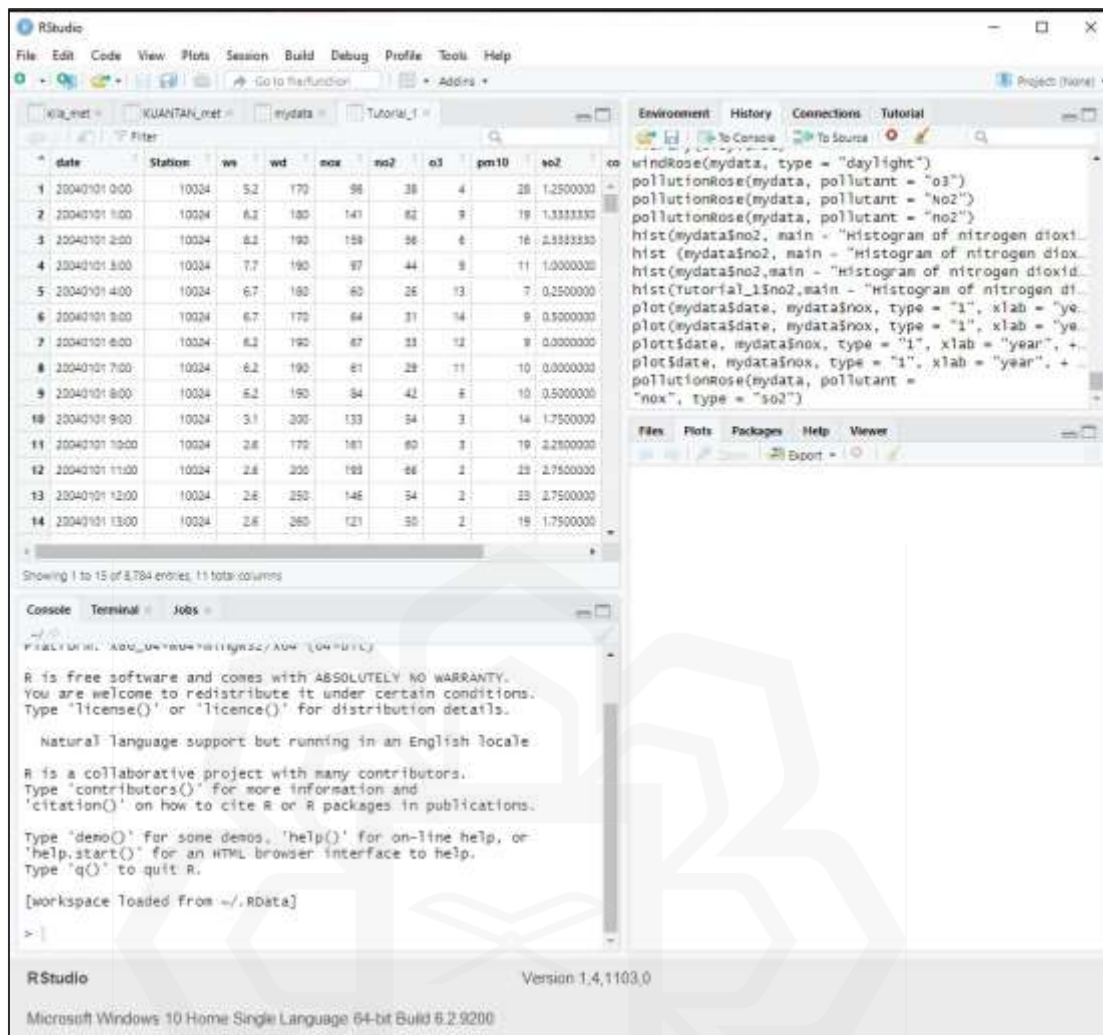


Figure 3.20 Example of the R studio display framework and platform for working data analyses.

The data PM_{2.5} and meteorological data will be imported into the right top of the panel known as Workspace. The dataset can be reviewed in the right top panel known as the R Script. Figure 3.28 shows the command coding that we need to generate the graph is done in the console panel at the right bottom. The command coding must be clear for the software to be rerun. Any undesired graph can be edited in the future in this console. The graph and plots appear at the bottom right panel. The RStudio is flexible in use on the environmental project as it can be used for a long-term project and continuous dataset.

The command coding must be exactly the code that we request to instruct the software to run. RStudio is free to download, and it is under licensed GNU (General Public License). The simplicity of the programming language makes RStudio popular with users by researchers and scientists.

To open the R studio, need to install it on the desktop. In this study, R studio was downloaded with 64 bits. The **openair** package needs to be uploaded for the first time and the input data requirement. Figure 3.31 shows the installation of R studio on the desktop computer. These packages need to be installed to perform any analyse in R, but the packages must be developed and published by R. Programmer packages or extensions other than R cannot be installed or run its programmed in R.

library (openair)	library (dplyr)
library (tidyverse)	library (lattice)
library (tidyr)	library (lubridate)
library (ggplot2)	

The **Openair** is a package mainly used to analyse air pollution data. The **openair** package is installed once and it needs to be continually updated in terms that will know the document that needs to be analysed are using R version 3.6.1 and **openair** version 2.6-6. If the package is uninstalled, the Rstudio will malfunction and a coding error will be shown in the R console to alert the user.



```

Console: Terminal | Jobs
~/data modeling/ >
warning message:
package 'openair' was built under R version 4.0.3
> library(tidyverse)
-- Attaching packages ---- tidyverse 1.3.0 --
v ggplot2 3.3.3   v purrr  0.3.4
v tibble  3.0.6   v dplyr  1.0.4
v tidyr   1.1.2   v stringr 1.4.0
v readr   1.4.0   v forcats 0.5.1
-- Conflicts ---- tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
> library(tidyr)
> library(lubridate)
Attaching package: 'lubridate'
The following objects are masked from 'package:base':
  date, intersect, setdiff, union
> library(readr)
> library(ggplot2)
> |
  
```

Figure 3.21 Installing the package into the platform before starting analyses.

3.7.2 Openair Functions

Understanding coding and defining the core function of coding that needs to be applied in **openair** will provide good summarizing in presenting the input. Several coding instructions that are suitable or not suitable depending on what we want to describe our analyses. Table 3.6 shows the core function used in this research study, the mandatory variables, and the purpose of the R console. The main purpose of functions is to help rapidly visualize the significant potential complex data in the form of a familiar way.

Table 3.6 Function, mandatory variable and purpose used in R Studio

Function	Mandatory variables	Purpose
<code>calendarPlot</code>	date, one numeric field	Calendar-type view of the mean values
<code>percentileRose</code>	wd, one other numeric field	Percentiles by wind direction
<code>polarPlot</code>	ws, wd, one other numeric field	Bi-variate polar plot
<code>pollutionRose</code>	ws, wd, one other numeric field	Pollution rose
<code>windRose</code>	date, ws, wd	Traditional wind rose

The commands in R software are given in colour coding. The Code in **red** represents punctuation and commands that need to be entered. While code in **blue** represents names that will change depending on the context of the problem such as variable names or dataset names. In an **openair** project, the package has many functions which work reliably. `modellingData1` is the raw data file that I use and save information of table data in an excel file and apply in R. `windrose` if the function.

```
functionName (thedata, option..) => windRose (modellingData1)
```

```
windRose(modellingData1)
```

```
# Code for Wind Rose
```


other function coding used in this research are as: -

```
calenderPlot(modellingData1)
```

```
# Code for calendar Plot
```

```
percentileRose(modellingData1)
```

```
# Code for percentile Rose
```

Different writing coding in the bivariate polar plot ([polarPlot](#)). The type of pollutant needs to mention in writing the coding to specify the type of pollutant need to analyse. Example as below

```
polarPlot(modellingData1, pollutant = "PM2.5", type = "month" )
```

Figure 3.33 below shows the function of pollution rose implemented in the R console. The data which is [modellingData1](#) is analyzed and the pollutant PM_{2.5} concentration is defined. The coding must be correctly in line and well define as the computer can read the command that we insist on only. The output is shown beside the R console at the right end of the plot section. The output result from analyses is easy to been seen as it is in the same display. Making any corrections or changes in data analyses can be done straightforwardly by adding new import data from other sources.

The make changes in the colour scale of petals of pollution rose also can be done in R console. The colour scale is in [openColours](#) function package where you can find several pre-defined schemes or a user-defined scheme. This colour is known as Viridis. The viridis R package was developed by Simon Garnier and provides colour palettes to make perceptually uniform, easy to read, a printer friendly and to present in a beautiful plot for research or report output. To use the Viridis it needs to be install and download the package.

```
Install. Packages ("viridis")
```

```
#Install
```

```
Library ("viridis")
```

```
# Load
```

Figure 3.32 show the colour scales that are provided in Rstudio. The defined scheme can be such as c (tomato, white, forest green), greyscale, inferno, viridis, jet,

heat, increment, and default. Whereas the user defines the scheme, we can set the type of colour scales that need to be used in the output of the result.

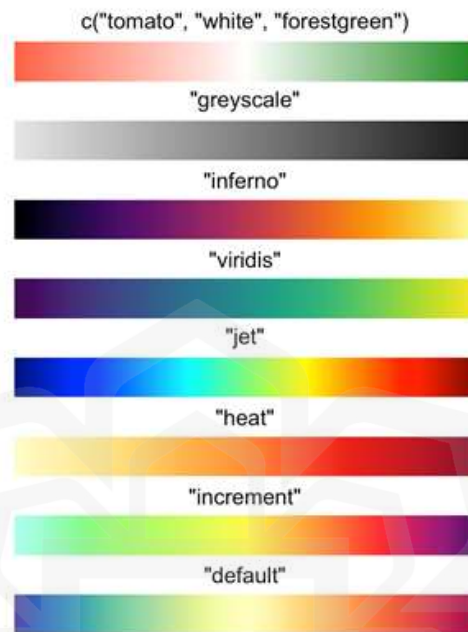


Figure 3.22 List of colour scales in [openColour](#) function

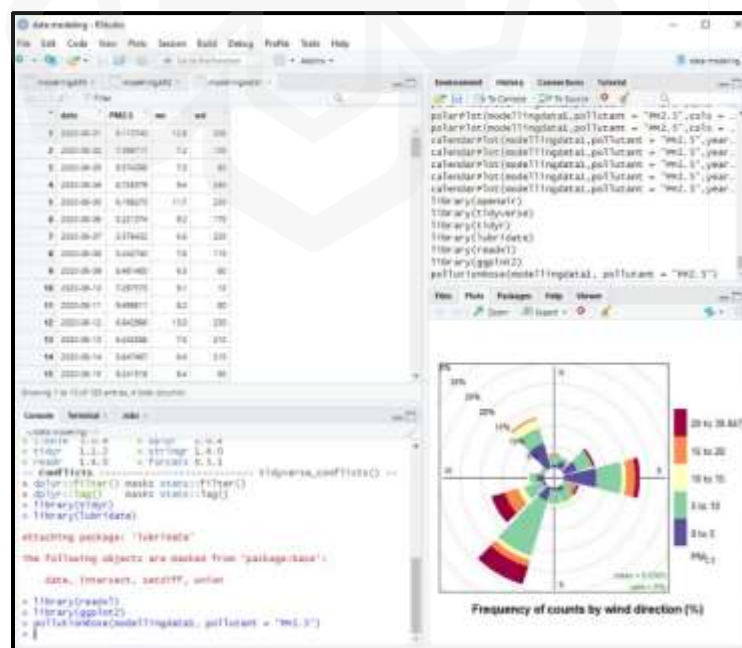


Figure 3.23 Pollution rose function in R studio determine PM_{2.5} concentration dispersion. The output of pollution rise is shown at the right end of R console.

3.7.3 Adjust Time in R studio

Before starting to analyze data in R, the time zone needs to be clear and fixed according to the GMT/UTC. For Malaysia time zone is set as `tzzone = "MYT/GMT+8"` In this case, **lubridate** need to open in **openair** for matting the dates and times to avoid complexity faced by the user. Below is the example formatting date before starting the R software:

```
library(lubridate)
```

```
dmy("1/6/2020")
```

```
## [1] "2020-06-01"
```

or

if the data contents time example

as below:

```
dmy_hm("1/6/2020 12:00")
```

```
## [1] "2020-06-01 12:00:00 UTC"
```

In the R console the date format will be typed as follow:

```
>modellingData1$date <- as.POSIXct(strptime(modellingData1$date, format =  
"%d/%m/%Y %H:%M", tz = "GMT"))
```

The R studio is a relevant use for any environmental data, especially in air quality monitoring. The availability of the Windrose function and other commands make it simple and easy to use. However, without proper code or incorrect commands or incorrect data implementation, the R studio can't function as the computer can't understand the command to be analysed. Other than that, the input data frame such as meteorological data, pollution and date/time must be saved in a file such as a .csv file or .xl file.

The distribution of PM_{2.5} will be shown in the form of a polar plot where a graphical impression is used to show the concentration in the study. In R studio the function plots the Bivariate polar plot. The Bivariate polar plot plots the PM_{2.5} concentration with different wind directions and wind speed. When high wind speed,

normally the result will be lower concentration dispersion due to an increase of mechanical turbulence and through advection that increases dilution.

In the Bivariate polar plot, the PM_{2.5} data concentration, wind direction, and wind speed are divided into wind speed-direction bin and each bin will be calculated using mean concentration. In a Bivariate polar plot, the wind components, u and v are calculated as follows:

$$u = \bar{u} \cdot \sin\left(\frac{2\pi}{\theta}\right), v = \bar{u} \cdot \cos\left(\frac{2\pi}{\theta}\right)$$

where $\bar{u}$ is the mean hourly wind speed and θ is the mean wind direction in degrees with 90° as being from the east. For u and v is the concentration surface.

3.8 WELCH'S TEST

Many studies today prefer using the Welch's T-Test where it has become increasingly popular due to its flexibility and robustness when dealing with real-world data. According to Lu *et al.* (2010) Welch's t-test is used when two tested variances mean from independent population are not equal. Welch's t-test provides accurate control of the Type I error and it is simple to use. The Welch obtained the approximated t distribution when comes to two populations are not equal.

3.8.1 Study Design and Data Collection

This study employed a comparative quantitative approach to assess particulate matter concentrations (PM₁₀ and PM_{2.5}) using data from two sources: the S1 Monitoring Site (in-situ data) and the DOE Monitoring Site (secondary data). The in-situ data from the S1 Monitoring Site were collected over a six-month period, spanning from June to November 2020, and represented localised air quality measurements. The secondary data from the DOE Monitoring Site, obtained for the same period, provided regional air quality metrics based on standardized monitoring practices.

3.8.2 Variables and Measurement

The primary variables analyzed in this study were particulate matter concentrations, specifically PM₁₀ and PM_{2.5}, measured in micrograms per cubic meter (µg/m³). The S1 Monitoring Site utilized in-situ equipment to record real-time pollutant levels, capturing local environmental variations. The DOE Monitoring Site data were collected using regional monitoring instruments calibrated to national air quality standards, ensuring consistency in reported values.

3.8.3 Statistical Analysis

Descriptive statistics, including mean, standard deviation, and sample size, were calculated for both datasets to summarize the data distribution. An independent samples t-test was conducted for both PM₁₀ and PM_{2.5} concentrations to determine whether there were statistically significant differences between the two data sources. Given the violation of equal variances as indicated by Levene's test, Welch's t-test was employed to account for unequal variances. All statistical analyses were performed using *Jamovi* (2022), a user-friendly statistical software, with statistical significance set at a p-value of < 0.05.

The dataset was organized into three columns: Group, PM₁₀, and PM_{2.5}. The Group column represented the data source (categorized as "S1" for in-situ data and "DOE" for secondary data). The PM₁₀ and PM_{2.5} columns contained the respective particulate matter concentrations (measured in µg/m³). Each row represented a single observation, and care was taken to ensure that all data were entered accurately and assigned to the correct group. Once the data was fully entered, it was saved in *Jamovi*'s native format for analysis.

i. Descriptive Statistical Analysis

The descriptive statistics for the dataset were generated using the Descriptives module in *Jamovi*. This involved navigating to the 'Analyses' tab and selecting 'Exploration' > 'Descriptives.' The continuous variables, PM₁₀ and PM_{2.5}, were added

to the 'Variables' box, while the Group variable was placed in the 'Split by' box to allow for a comparison of descriptive metrics across the two data sources (S1 and DOE). This analysis produced key summary statistics, including the mean, median, and standard deviation. These outputs provided an overview of the data distribution and variability for both PM₁₀ and PM_{2.5} concentrations.

ii. Independent t-test

The t-test is a widely used statistical tool for evaluating whether the mean values of two groups differ significantly. It is particularly useful in comparative analyses to test hypotheses related to group differences. Specifically, the independent samples t-test is applied when the two groups being compared are separate and unrelated, such as data obtained from distinct populations or sources. When the assumption of equal variances between groups is not met, Welch's t-test is used as an alternative, offering a more reliable analysis. This method produces a t-statistic and a p-value, which help determine the probability that the observed differences are due to random variation.

An independent samples t-test was performed to assess whether there were statistically significant differences in particulate matter concentrations between the S1 and DOE Monitoring Sites. This was achieved by selecting the 'T-Tests' module under the 'Analyses' tab and choosing 'Independent Samples T-Test.' The PM₁₀ variable was added to the 'Dependent Variables' box, and the Group variable was placed in the 'Grouping Variable' box. The same process was repeated for PM_{2.5}. To account for unequal variances, the 'Assume Equal Variances' option was unchecked, thereby applying Welch's t-test. The analysis generated the t-statistic, degrees of freedom, and p-value for each comparison. The process methodology is in Appendix G.

3.9 CONCLUSION

This research's analysis method and procedure must be planned and carefully performed to avoid several careless and missed procedures. The software chosen for this research is affordable and can run the analyses well. The Aeroqual can be calibrated by comparing its response at zero or PM_{2.5} or PM₁₀ standard. The zero stability ($\mu\text{g}/\text{m}^3$) is ± 0.1 . Only Aeroqual sensor head needs to be calibrated and all parameter install in the sensor head need to be calibrated. However, the base unit does not need to be calibrated.

Aeroqual is potable to be used in harsh environments or higher exposure level conditions. Still, it can lead to a reduction in life expectancy if exposed for long period. However, the accuracy of Aeroqual may drift along with the sensor ages used. All equipment may degrade same goes to Aeroqual sensor head it may degrade when unused and in storage.

The used of Aeroqual in construction can reduce risk and increase reputation in monitoring the dust at construction sites. It is advice that the site supervisor need to be responsible in monitoring dust and other particulate matter emitted at the site. Aeroqual provides real-time data that can sense where and when fugitive dust emissions might occur. This helps the supervisor to take action before any problems arise. The Aeroqual helps protect the surrounding communities by monitoring the particulate matter beyond the minimum compliance and standard requirements.

The Aeroqual software is free and can be downloaded by filling in the download link at the aeroqual.com/s500-software-registration. However, several computer requirements need to be fulfilled by the user such as more than 1 GHz processor speed, window OS version 2000 and later window are required, more than 512 Mb RAM and port and USB to monitor cable. However, iOS platforms are not supported.

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION OF RESULTS

4.1 INTRODUCTION

The data analysis and presentation of the result will define the output of the data monitoring and explanation of the result for better understanding. The output will be presented in form of a table, graph or chart for better understanding and to make it easier in performing the pattern. In this chapter, we will be explaining the result of the research monitoring that has been done over six (6) months period. The result will be divided into 3 categories:

- i. Result of descriptive analysis of particulate matter
- ii. Result of meteorology data
- iii. Result of PM_{2.5} pattern distribution

4.2 RESULT DESCRIPTIVE ANALYSIS FOR PM_{2.5} CONCENTRATION

Table 4.1 shows the results of the descriptive analysis for PM_{2.5} from June until November 2020. The data set is the cumulative data of PM_{2.5} collected continuously at the research site. The highest mean is determined in September with 19.51 $\mu\text{g}/\text{m}^3$ respectively, and the second highest is in August with 12.58 $\mu\text{g}/\text{m}^3$, followed by 10.86 $\mu\text{g}/\text{m}^3$ in October, 6.47 $\mu\text{g}/\text{m}^3$ and 6.04 $\mu\text{g}/\text{m}^3$ respectively in July and June and the lowest mean is in November with 2.34 $\mu\text{g}/\text{m}^3$ respectively. For median value, the highest median is in September with 18.03 $\mu\text{g}/\text{m}^3$, followed by 10.32 $\mu\text{g}/\text{m}^3$ in August, 8.53 $\mu\text{g}/\text{m}^3$ in October, 6.13 $\mu\text{g}/\text{m}^3$ and 6.1 $\mu\text{g}/\text{m}^3$ respectively in July and June and the lowest median is in November with 1.89 $\mu\text{g}/\text{m}^3$ respectively.

Table 4.1 The descriptive analysis of PM_{2.5} from June to November 2020

Descriptive analysis	June	July	August	September	October	November
Mean	6.47	6.04	12.58	19.51	10.86	2.34
Median	6.10	6.13	10.32	18.03	8.53	1.89
Standard Deviation	1.54	1.99	7.44	11.08	6.47	1.44
Minimum	3.78	3.01	5.34	5.83	2.76	0.76
Maximum	9.49	10.77	33.88	38.65	24.85	5.65

Table 4.2 The descriptive analysis of PM₁₀ from June to November 2020

Descriptive analysis	June	July	August	September	October	November
Mean	10.71	11.30	41.99	85.92	43.16	6.36
Median	10.36	10.72	21.75	89.30	34.27	4.76
Standard Deviation	2.30	3.63	47.85	53.80	31.06	4.00
Minimum	6.86	5.64	9.26	10.48	5.44	2.29
Maximum	16.64	19.69	170.67	167.77	96.54	19.00

Standard deviation (SD) is shown in Table 4.1, the month of September was the highest SD with $11.9 \mu\text{g}/\text{m}^3$ respectively followed by August with $7.44 \mu\text{g}/\text{m}^3$, then, the month of October with $6.47 \mu\text{g}/\text{m}^3$, close together followed by July and June with $1.99 \mu\text{g}/\text{m}^3$ and $1.54 \mu\text{g}/\text{m}^3$ and the lowest standard deviation was in November with $1.44 \mu\text{g}/\text{m}^3$ respectively.

For minimum and maximum values, each month has a different minimum dan maximum value. In June, the minimum value is $3.78 \mu\text{g}/\text{m}^3$ and the maximum value is $9.50 \mu\text{g}/\text{m}^3$. In July, the minimum value is $3.01 \mu\text{g}/\text{m}^3$ and the maximum value is $10.77 \mu\text{g}/\text{m}^3$ respectively, the other month August the minimum value is $5.34 \mu\text{g}/\text{m}^3$ and the maximum value is $33.88 \mu\text{g}/\text{m}^3$ while, in September, the minimum value is $5.83 \mu\text{g}/\text{m}^3$ and the maximum value is $38.65 \mu\text{g}/\text{m}^3$ respectively, followed by October, the minimum value is $2.76 \mu\text{g}/\text{m}^3$ and the maximum value is $24.85 \mu\text{g}/\text{m}^3$ respectively. In November, the minimum value is $0.76 \mu\text{g}/\text{m}^3$ and the maximum value is $5.65 \mu\text{g}/\text{m}^3$ respectively.

4.3 RESULT DESCRIPTION ANALYSIS FOR PM_{10} CONCENTRATION

Table 4.2 shows the results description analysis for PM_{10} from June to November 2020 where the data was collected in situ at the research site where the highest mean is determined in September with $85.9 \mu\text{g}/\text{m}^3$, and the second highest is in October with $43.16 \mu\text{g}/\text{m}^3$, followed by $41.99 \mu\text{g}/\text{m}^3$ in August, $11.30 \mu\text{g}/\text{m}^3$ and $10.71 \mu\text{g}/\text{m}^3$ respectively in July and June and the lowest mean is in November with $6.36 \mu\text{g}/\text{m}^3$ respectively. For median value, the highest median is in September with $89.30 \mu\text{g}/\text{m}^3$, followed by $10.32 \mu\text{g}/\text{m}^3$ in August, $8.53 \mu\text{g}/\text{m}^3$ in October, $6.13 \mu\text{g}/\text{m}^3$ and $6.1 \mu\text{g}/\text{m}^3$ respectively in July and June and the lowest median is in November with $1.89 \mu\text{g}/\text{m}^3$ respectively.

Standard deviation (SD) in September was the highest SD with $53.80 \mu\text{g}/\text{m}^3$ respectively followed by August with $47.85 \mu\text{g}/\text{m}^3$, October with $31.06 \mu\text{g}/\text{m}^3$, close together followed by July and June with $3.63 \mu\text{g}/\text{m}^3$ and $6.86 \mu\text{g}/\text{m}^3$ and the lowest standard deviation was in November with $4.00 \mu\text{g}/\text{m}^3$ respectively.

For minimum and maximum values, each month has a different minimum and maximum value. In June, the minimum value is $6.86 \mu\text{g}/\text{m}^3$ and the maximum value is $16.64 \mu\text{g}/\text{m}^3$. In July, the minimum value is $5.64 \mu\text{g}/\text{m}^3$ and the maximum value is $19.69 \mu\text{g}/\text{m}^3$ respectively. In August the minimum value is $10.48 \mu\text{g}/\text{m}^3$ and the maximum value is $170.67 \mu\text{g}/\text{m}^3$. While, in September, the minimum value was $5.83 \mu\text{g}/\text{m}^3$ and the maximum value was $167.77 \mu\text{g}/\text{m}^3$ respectively, followed by October, the minimum value was $5.43 \mu\text{g}/\text{m}^3$ and the maximum value was $96.54 \mu\text{g}/\text{m}^3$ respectively. In November, the minimum value is $2.29 \mu\text{g}/\text{m}^3$ and the maximum value is $19.0 \mu\text{g}/\text{m}^3$ respectively.

4.4 WELCH'S T-TEST RESULT

The descriptive statistics for PM_{10} and $\text{PM}_{2.5}$ concentrations were calculated for both datasets: the S1 Monitoring Site (in-situ data) and the DOE Monitoring Site (secondary data). The mean (M), standard deviation (SD), and sample size (N) for each group are presented in Table 4.3. Data S1 is the data taken at the study site every day for 6 months for this study. This data was taken in hot weather and also during heavy rain. This particulate matter monitoring continuously collects its data without fail.

Table 4.3 Descriptive statistics of PM_{10} and $\text{PM}_{2.5}$ concentrations for S1 and DOE monitoring sites.

	GROUP	N	Mean	Median	SD	Variance	Minimum	Maximum
PM_{10}	DOE	6	17.00	17.59	2.51	6.29	12.84	19.4
	S1	6	33.30	26.29	30.88	953.86	6.50	87.3
$\text{PM}_{2.5}$	DOE	6	10.88	11.38	2.42	5.85	6.78	13.5
	S1	6	9.60	8.55	6.06	36.67	2.34	19.5

For PM_{10} concentrations, the mean value for the S1 Monitoring Site was $33.30 \mu\text{g}/\text{m}^3$ (SD = 30.88), indicating substantial variability in the data. In comparison, the DOE Monitoring Site had a lower mean PM_{10} concentration of $17.00 \mu\text{g}/\text{m}^3$ (SD = 2.51),

reflecting much smaller variability. The range of PM₁₀ values was broader for the S1 site (6.50 to 87.30 µg/m³) compared to the DOE site (12.84 to 19.40 µg/m³), further highlighting the localized fluctuations in the S1 data.

For PM_{2.5} concentrations, the mean value for the S1 Monitoring Site was 9.60 µg/m³ (SD = 6.06), while the DOE Monitoring Site recorded a slightly higher mean of 10.88 µg/m³ (SD = 2.42). Similar to PM₁₀, the standard deviation was smaller for the DOE data, suggesting more consistent PM_{2.5} levels across observations. The S1 site had a wider range of PM_{2.5} concentrations (2.34 to 19.50 µg/m³) compared to the DOE site (6.78 to 13.50 µg/m³), indicating greater variability in the localized data.

4.4.1 Particulate Matter (PM₁₀) Concentrations

The concentration of PM₁₀ was analyzed from two datasets: in-situ data collected at the S1 Monitoring Site and secondary data obtained from the DOE Monitoring Site. Descriptive statistics revealed variability in PM₁₀ levels between the two sources. An independent samples t-test using Welch's method was conducted to determine whether there was a significant difference in PM₁₀ concentrations between the two datasets.

Table 4.4 showed a mean PM₁₀ concentration of 33.30 ± 30.88 µg/m³ for the S1 Monitoring Site and 17.00 ± 2.51 µg/m³ for the DOE Monitoring Site. Welch's t-test indicated no statistically significant difference between the two groups, $t = 1.29$, $p = 0.253$.

Table 4.4 Results of independent samples t-tests for PM₁₀ concentrations

		Statistic	df	p
PM ₁₀	Welch's t	-1.29	5.07	0.253

This indicates that the variation in PM₁₀ levels observed between the two monitoring methods may not be substantial enough to reflect a true difference, and the variations are likely attributable to sampling or measurement conditions rather than systematic differences in air quality.

4.4.2 Particulate Matter (PM_{2.5}) Concentrations

Descriptive statistics highlighted variability in PM_{2.5} levels between the S1 and DOE Monitoring Sites. An independent samples t-test using Welch's method was conducted to assess differences in PM_{2.5} concentrations between the two groups. Table 4.5 shows the mean PM_{2.5} concentration for the S1 Monitoring Site was $9.60 \pm 6.06 \mu\text{g}/\text{m}^3$, while the DOE Monitoring Site recorded a mean concentration of $10.88 \pm 2.42 \mu\text{g}/\text{m}^3$. Welch's t-test indicated no statistically significant difference between the two groups, $t = 0.48$, $p = 0.646$.

Table 4.5 Results of independent samples t-tests for PM_{2.5} concentrations

		Statistic	df	p
PM _{2.5}	Welch's t	0.482	6.56	0.646

The slightly higher mean PM_{2.5} concentration in the DOE Monitoring Site compared to the S1 Monitoring Site is not statistically meaningful, suggesting that the differences may again be due to random variation or differences in monitoring equipment calibration or methodology.

4.5 PARTICULATE MATTER, PM_{2.5} AND PM₁₀ CONCENTRATION

The average trend of PM_{2.5} and PM₁₀ for monthly monitoring has fluctuated depending on the activity at the construction site and meteorological factors in that particular month. Each graph is compared to the New Malaysia Ambient Air Quality Standard 2020 (MAAQS) on 24-hour average exposure for PM_{2.5} should not exceed 35 µg/m³ and PM₁₀ should not exceed 100 µg/m³. Justification MAAQS indicate PM_{2.5} at or below 35 µg/m³ (24 hours) and PM₁₀ at or below 100 µg/m³ are considered healthy with small to no risk from prolonged exposure. But, if the level reaches or above 35 µg/m³ (PM_{2.5}) or 100 µg/m³ (PM₁₀) during 24 hours, the air quality is considered unhealthy and can cause health problems to at-risk groups who suffer from asthma, heart disease, acute and chronic bronchitis.

4.5.1 The Trend of PM_{2.5} Concentration

Figure 4.1 shows the result of PM_{2.5} concentration in June 2020. The graph fluctuated and showed a sideways trend. The graph shoots up from 6.11 µg/m³ on 1st June to 8.57 µg/m³ on 3rd June 2020. The graph gradually decreases from 4th June to 8th June 2020 with 5.24 µg/m³ respectively. The graph rises significantly to 9.50 µg/m³ (the maximum peak) on 11th June 2020; however, the graph decreases to 5.65 µg/m³ on 14th June 2020. The graph rises to 9.24 µg/m³ on 15th June 2020 but drops sharply to 3.79 µg/m³ on 16th June 2020. On 17th June the graph rose rapidly to reach 8.64 µg/m³ but the graph dramatically decreased to 4.37 µg/m³ on 21st June 2020. Then, the graph gradually increases from 23rd June to 26th June 2020 with 6.75 µg/m³ respectively. The graph again decreases to 4.98 µg/m³ on 28th June but rises sharply on 29th June 2020 with 9.26 µg/m³. The high peak is 9.50 µg/m³ and the lowest concentration is 3.78 µg/m³. The PM_{2.5} concentration in June are within the Malaysia Ambient Air Quality Standard.

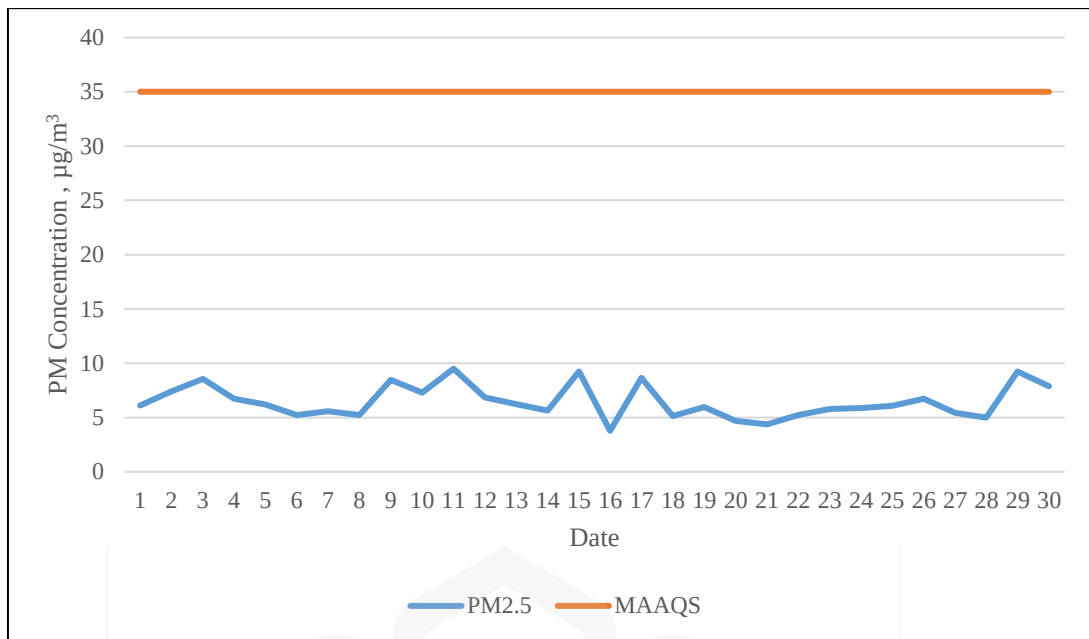


Figure 4.1 PM_{2.5} concentration in June 2020

PM_{2.5} concentration that was monitored in July 2020 was shown in Figure 4.2. The 1st of July showed the highest peak of the month with 10.77 µg/m³ and until the 5th of July, the graph dropped from 10.77 µg/m³ to 4.53 µg/m³. The graph went up from 6th to 9th July at 7.74 µg/m³. Then the graph declined to 4.92 µg/m³ and fluctuated until it decreased on 13th July to 8.47 µg/m³. The graph gradually decreased from 7.65 µg/m³ to 3.01 µg/m³ from the 14th to the 21st of July. On 22nd July, the graph went up steadily to 6.73 µg/m³ on 25th July. The graph falls deeply and then surges up 10.73 µg/m³ on 30th July. The graph continues to decrease to 6.73 µg/m³ on the next day. The highest PM_{2.5} concentration in July is 10.77 µg/m³ and the lowest is 3.01 µg/m³. The PM_{2.5} concentration in July are within the Malaysia Ambient Air Quality Standard.

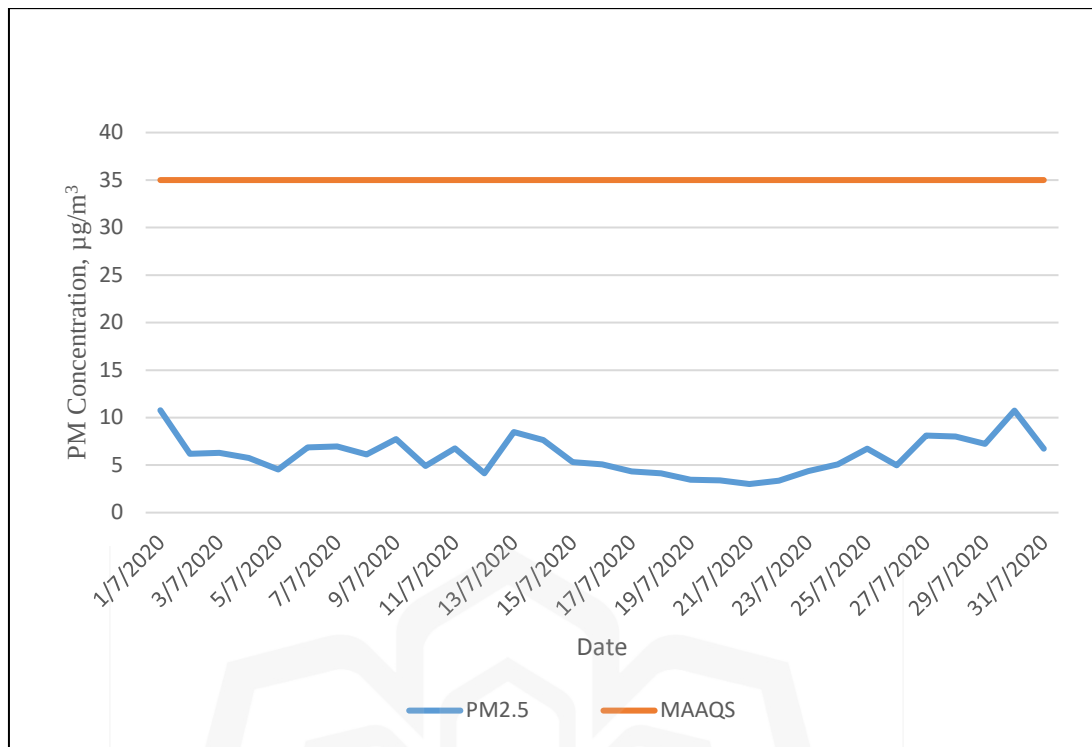


Figure 4.2 PM_{2.5} concentration in July 2020

Figure 4.3 shows the PM_{2.5} concentration that was monitored in August 2020. In August, the graph from the end of July rose to 1st August with 10.09 µg/m³. The graph fluctuated from 1st August till 5th August with 11.28 µg/m³. Suddenly the graph fell to 5.34 µg/m³ on 9th August and shot up to 16.71 µg/m³ on 10th August. The graph fluttered until it dropped on 16th August with 6.73 µg/m³. The graph started to increase to 8.14 µg/m³ and it fluctuated entire days and decreased again to 6.55 µg/m³ on 23rd August. The graph rises rapidly to 33.88 µg/m³ on 27th August which is the highest peak of the month. However, the graph slumped down to 5.63 µg/m³ on 30th August 2020, and has a sharp increase on 31st August to 18.53 µg/m³ respectively. The highest PM_{2.5} concentration in July is 10.77 µg/m³ and the lowest is 3.01 µg/m³. The PM_{2.5} concentration in August are within the Malaysia Ambient Air Quality Standard.



Figure 4.3 PM_{2.5} concentration in August 2020

The PM_{2.5} concentration in Figure 4.4 shows was monitored in September 2020. The graph continues to rise from 31st August 2020 to reach 28.85 µg/m³ on 3rd September 2020. Suddenly, the graph declines sharply to 6.68 µg/m³ on 6th September 2020. Yet, the graph rocketed to 33.88 µg/m³ on 9th September 2020. The graph is tumbled down to 7.13 µg/m³ on 10th September 2020. The graph increased from 7.13 µg/m³ to 9.84 on 12th September and slightly decrease to 7.42 µg/m³ on 13th September. The graph skyrocketed to 38.60 µg/m³ from 13th September to 17th September 2020. The graph falls speedily to the lowest peak with 5.84 µg/m³ on 21st September 2020. The graph shoots up to 19.46 on 22nd September and continues to fluctuate to 19.68 µg/m³ on 24th September. The graph falls gradually to 6.75 µg/m³ on 27th September 2020 but the graph rapidly increases to 38.65 µg/m³, the highest peak on 28th September 2020. The graph steadily drops to 34.94 µg/m³ on 30th September 2020. In September the highest PM_{2.5} concentration is 38.65 µg/m³ and the lowest concentration is 5.83 µg/m³. There are 6 value PM_{2.5} concentration in September that exceed Malaysia Ambient Air Quality Standard.

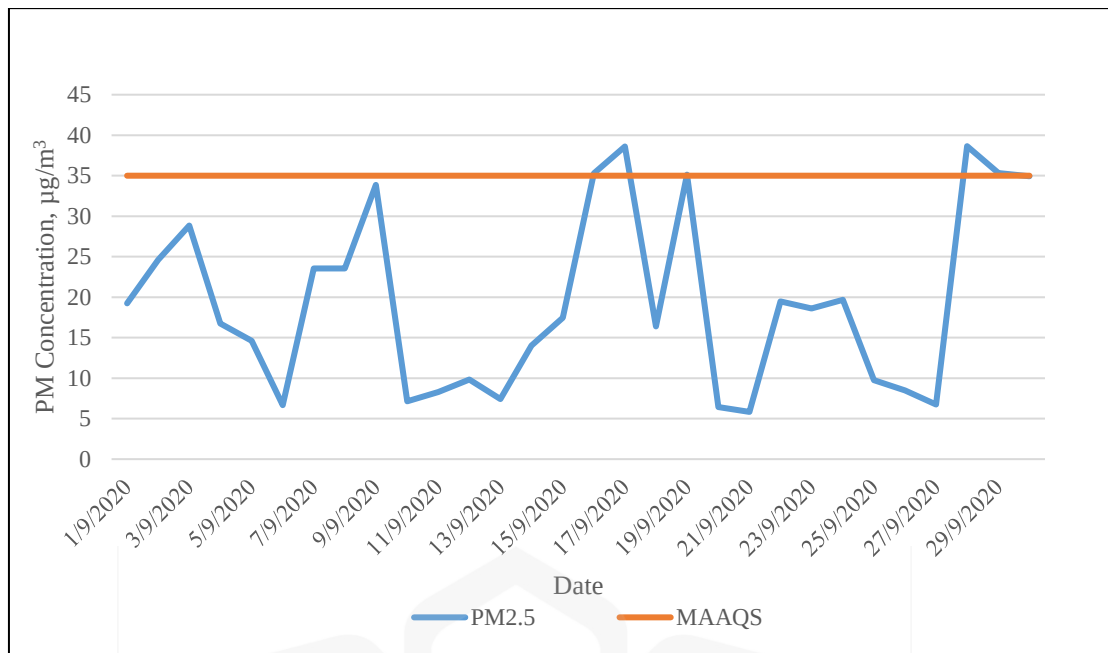


Figure 4.4 PM_{2.5} concentration in September 2020

The PM_{2.5} concentration was monitored in October 2020 (Figure 4.5). The graph sharply decreased from 34.94 µg/m³ on 30th September to 5.48 µg/m³ on 1st October 2020. But the graph shoots up from 5.48 µg/m³ to 24.85 g µg/m³ on 3rd September. Then, the graph drops to 6.64 µg/m³ on the 4th of October and suddenly rockets to 23.03 µg/m³ on the next day. The graph drops to 13.38 µg/m³ on 6th October and gradually increases to 21.86 µg/m³ on 10th October 2020. A sharp drop on 11th October 2020 with 6.94 µg/m³ and the graph starts to fluctuate onwards until it reaches 15.9 µg/m³ on 17th October. The graph starts to drop again until it reaches 2.93 µg/m³ on 26th October. The graph crawls upward to 8.53 µg/m³ on 27th October and fluctuates until it reaches 7.08 µg/m³ on 31st October 2020. The PM_{2.5} concentration in October is within the Malaysia Ambient Air Quality Standard.

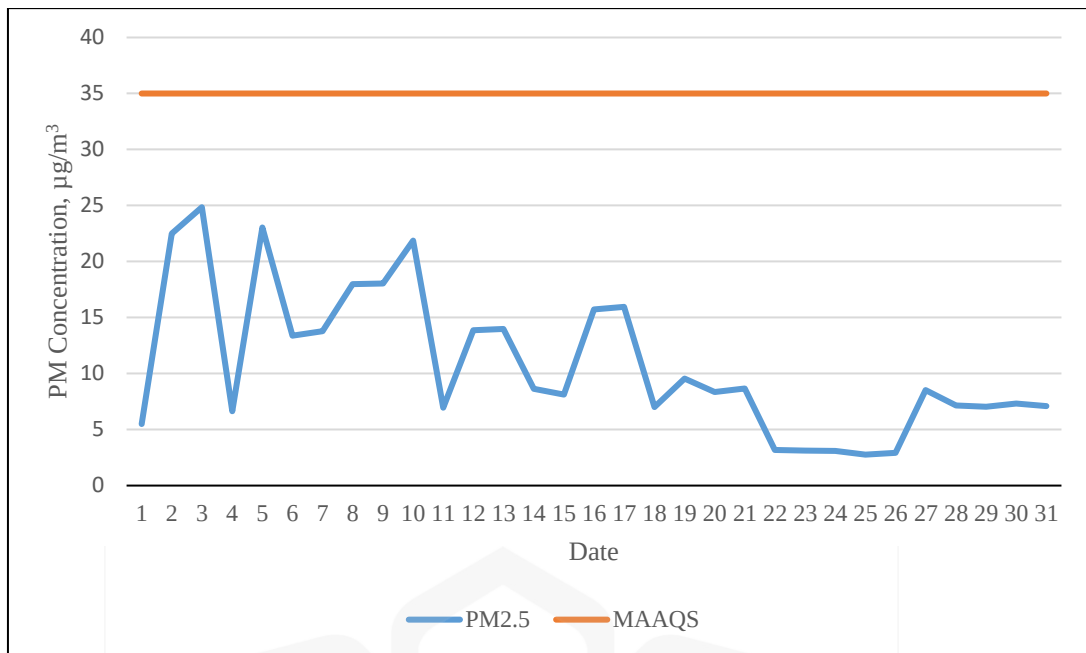


Figure 4.5 PM_{2.5} concentration in October 2020

Figure 4.6 shows the PM_{2.5} concentration that was monitored in November 2020. The graph dropped from 7.08 µg/m³ to 2.34 µg/m³ from 31st October to 1st November. The PM_{2.5} concentration gradually decreased from 2.34 µg/m³ to 1.79 µg/m³ on 8th November. The trend continues to go up and reaches 4.05 µg/m³ on 10th November but declines to 2.78 µg/m³ on 13th November. The graph increases to 5.65 µg/m³ on 16th November yet continues to decrease to 1.35 µg/m³ on 19th November 2020. A short increase to 2.05 µg/m³ on 20th November but continue to fall again to 0.76 µg/m³ (the lowest peak in the month). The graph has a minor increase and its reaches 0.96 µg/m³ on 30th November 2020. The PM_{2.5} concentration in November are within the Malaysia Ambient Air Quality Standard.

However, in November 2020 that graph pattern declined gradually throughout the month. The research site is not operated on Sunday, therefore, every week the graph will reach a lower peak and start to increase on the next day. In the month of November, the graph shows decrease as this month there is a high in rainfall and humidity value. The monsoon season also has an impact as it brings heavy rain. The activity such as filling and levelling, and the movement of lorry inside the construction site area reduces. Therefore, the emission of PM_{2.5} from the construction site has in low PM_{2.5} concentration value.

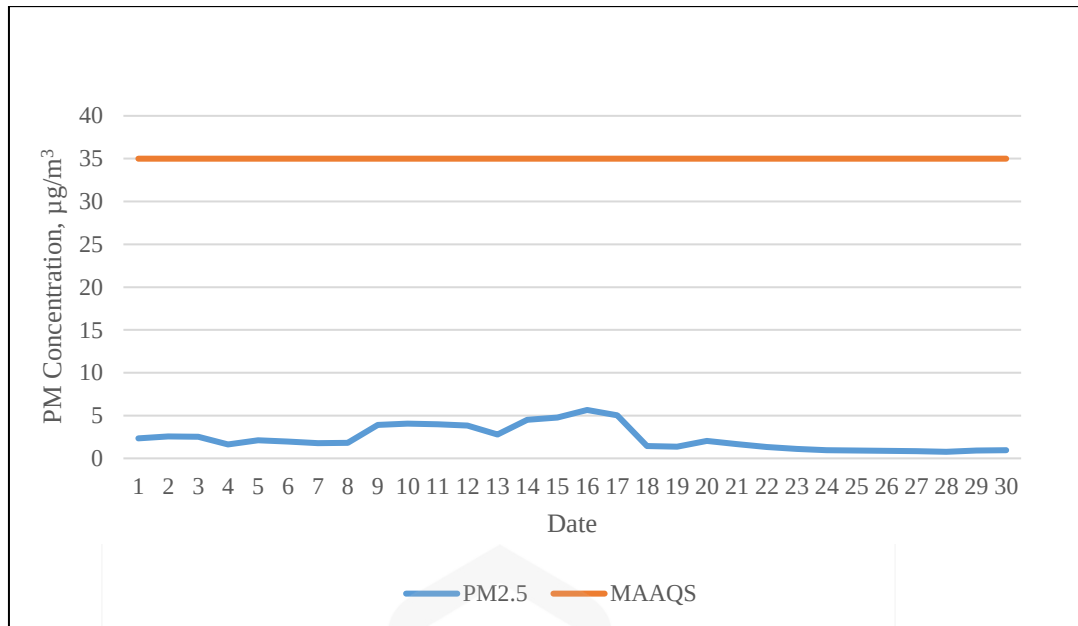


Figure 4.6 PM_{2.5} concentration in November 2020

4.5.2 The Trend of PM₁₀ Concentration

Figure 4.7 shows the PM₁₀ concentration that was monitored in June 2020. The maximum PM₁₀ concentration is 6.86 µg/m³ and the maximum PM₁₀ concentration is 16.64 µg/m³. The early trend PM₁₀ shows slight increases with 11.67 µg/m³ and continues to drop on 7th June with 7.46 µg/m³. Then, the trend increases by 13.95 µg/m³ but fluctuates until it drops again to 6.86 µg/m³ on 21st June 2020. The graph starts to crawl up and reach the high peak of 16.0 µg/m³ on 26th June 2020. The graph sharply decreased to 7.57 µg/m³ on 28th June 2020 and shot up to the highest point of 16.64 µg/m³ on 29th June 2020. The graph fluctuated may be due to low activity if compared to other months. In June, the research site experienced rainy days and it slowed down the construction activities. The PM₁₀ concentration in June are within the Malaysia Ambient Air Quality Standard.

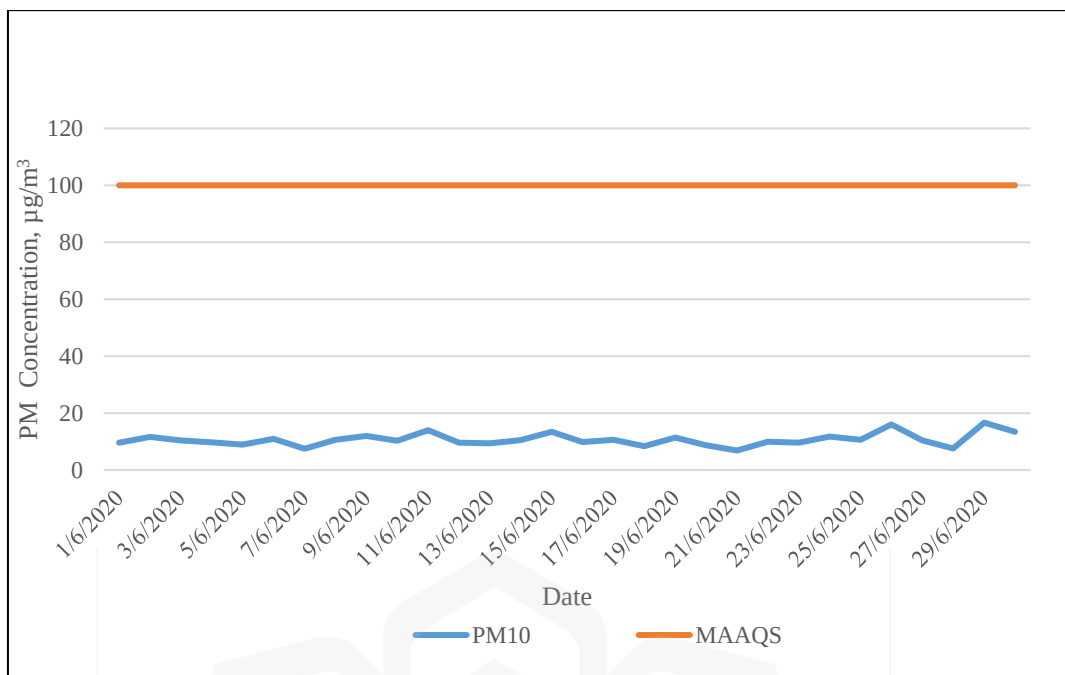


Figure 4.7 PM₁₀ concentration in June 2020

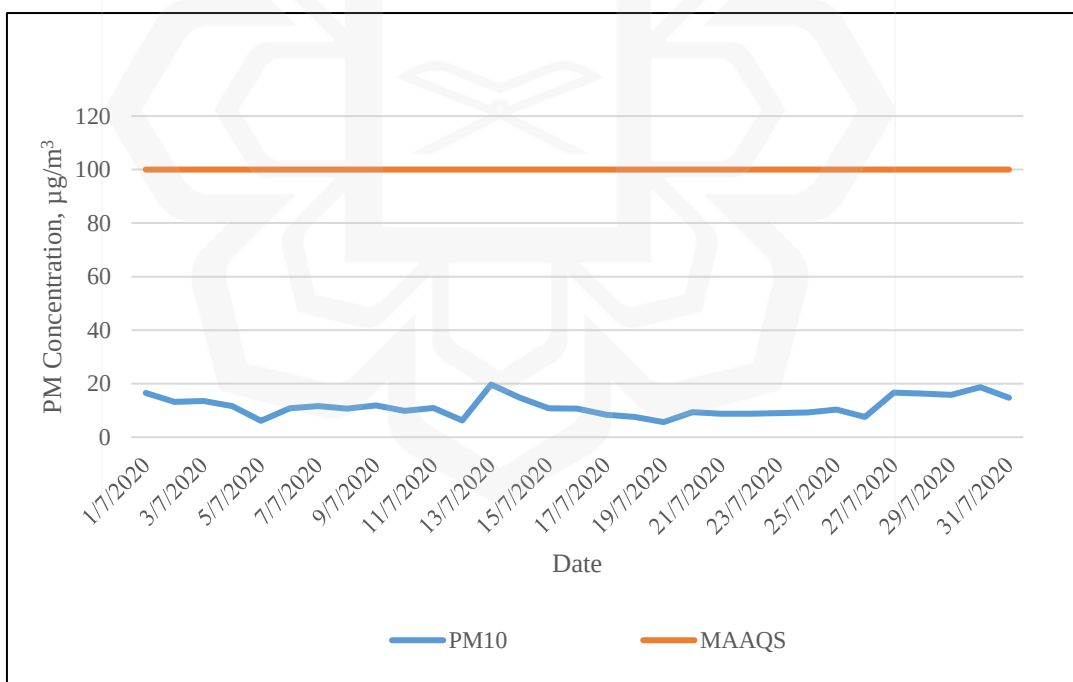


Figure 4.8 PM₁₀ concentration in July 2020

In July 2020, the maximum value was $19.69 \mu\text{g}/\text{m}^3$ and the minimum value was $5.64 \mu\text{g}/\text{m}^3$ was shown in Figure 4.8. The graph starts with $16.59 \mu\text{g}/\text{m}^3$ and gradually decreases to $6.12 \mu\text{g}/\text{m}^3$ on 5th July 2020. It is quite drastically the down of the graph but then it starts to $11.64 \mu\text{g}/\text{m}^3$ increase fluctuates and drops again on 12th July with $6.22 \mu\text{g}/\text{m}^3$. Then, the graph sharply increases to the highest point of $19.90 \mu\text{g}/\text{m}^3$ on 13th July. The graph experienced a downfall until it reached $7.58 \mu\text{g}/\text{m}^3$ on 18th July, continued to fluctuate and dropped again on 26th July with $7.58 \mu\text{g}/\text{m}^3$. The graph then sharply reaches $16.67 \mu\text{g}/\text{m}^3$ on 27th July and continues gradually until 31st July with $14.73 \mu\text{g}/\text{m}^3$. In July the trend of PM_{10} concentration at construction activity is slightly fluctuating due to the availability of rain which limits the movement of activities in the construction site. The PM_{10} concentration in July are within the Malaysia Ambient Air Quality Standard.

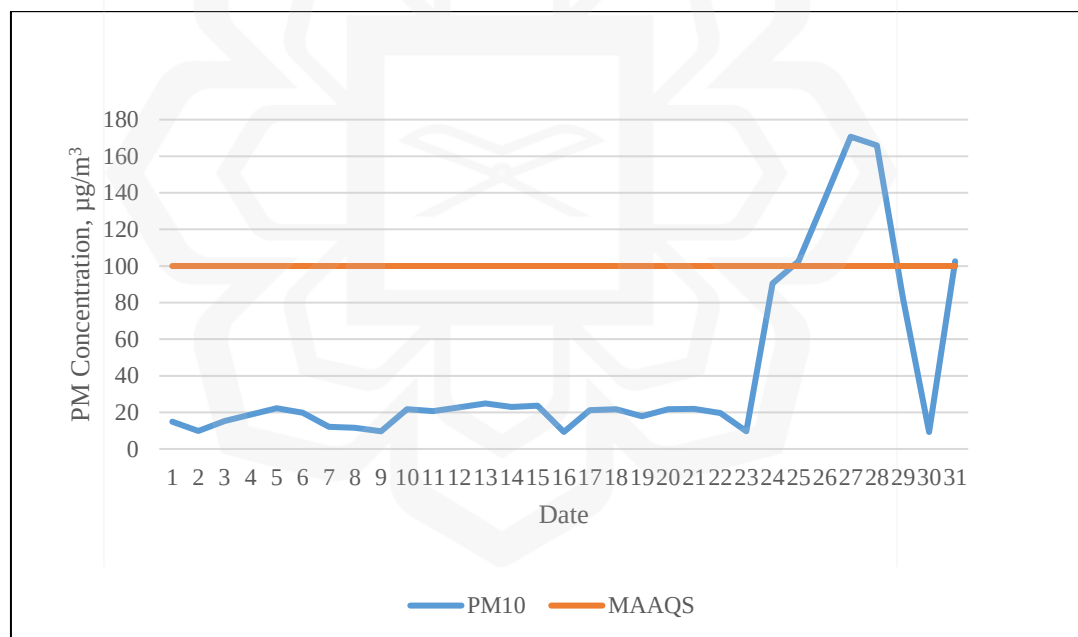


Figure 4.9 PM_{10} concentration in August 2020

The minimum value of $9.26 \mu\text{g}/\text{m}^3$ and the maximum value is $170.67 \mu\text{g}/\text{m}^3$ in August (Figure 4.9). The graph starts with $14.88 \mu\text{g}/\text{m}^3$ on 1st August 2020 and increases steadily to $22.20 \mu\text{g}/\text{m}^3$ on 5th August. The graph begins to drop slowly until it reaches $9.73 \mu\text{g}/\text{m}^3$ on 9th August and increases steadily until 15th August with $23.73 \mu\text{g}/\text{m}^3$. The graph remains stable until it decreases on 23 August with $9.68 \mu\text{g}/\text{m}^3$. The graph

dramatically increases until it reaches $170 \mu\text{g}/\text{m}^3$ on 27th August 2020. Then the graph slowly decreased and reached $165 \mu\text{g}/\text{m}^3$ on 28th August. However, the PM_{10} concentration sharply decreased to $9.26 \mu\text{g}/\text{m}^3$ on 30th August and increased sharply on the next day to $102.57 \mu\text{g}/\text{m}^3$. In August the value concentration of PM_{10} was above more than $14 \mu\text{g}/\text{m}^3$ compared to previous months. There is a high construction activity that occurred during this month that emits high PM_{10} emissions from the construction site heavily. The PM_{10} reaches more than $100 \mu\text{g}/\text{m}^3$ for 5 times in the month. There are 5 value PM_{10} concentrations in August that exceed Malaysia Ambient Air Quality Standard.

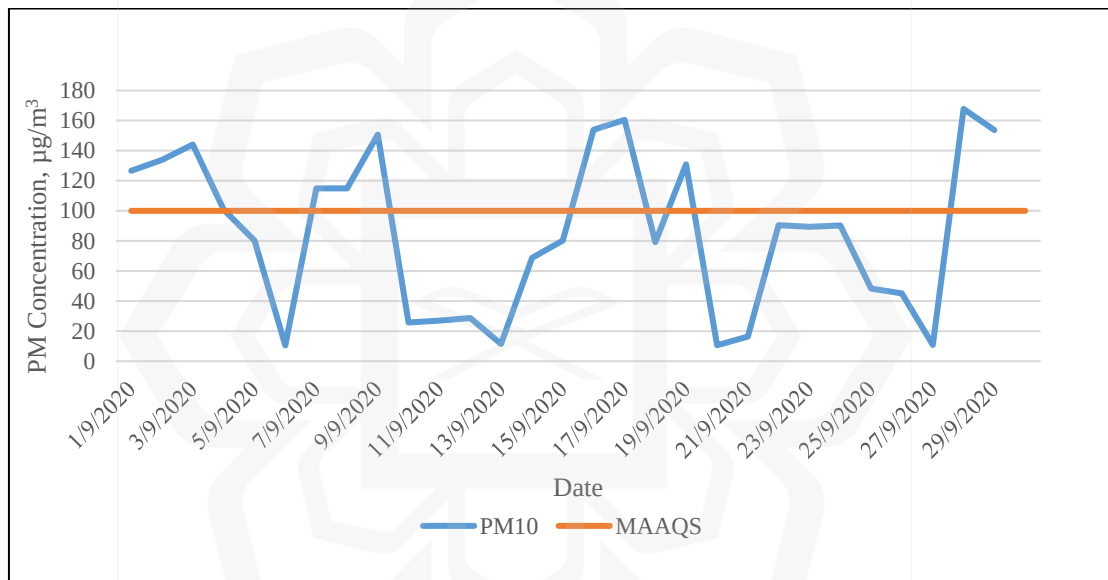


Figure 4.10 PM_{10} concentration in September 2020

Figure 4.10 shows the minimum value of $10.48 \mu\text{g}/\text{m}^3$ and the maximum value of $167.77 \mu\text{g}/\text{m}^3$ in September 2020. Starting with $126.69 \mu\text{g}/\text{m}^3$ on 1st September and increasing gradually to $144.12 \mu\text{g}/\text{m}^3$ on 3rd September. The graph then slowly decreased to $100 \mu\text{g}/\text{m}^3$ and continued to decrease again to $80.27 \mu\text{g}/\text{m}^3$ on 5th September. The graph sharply increases on the next day and reaches $150.79 \mu\text{g}/\text{m}^3$ on 9th September. The graph decreased its pattern to $11.43 \mu\text{g}/\text{m}^3$ on 13th September. But then, the graph growth rocketed to reach $160.42 \mu\text{g}/\text{m}^3$ the highest point on 17th September and fluctuated and decreased again on 20th September to $10.64 \mu\text{g}/\text{m}^3$. The graph slightly increased and reached $90.14 \mu\text{g}/\text{m}^3$ on 24th September and started to

decline from 25th to 27th September. However, the graph rises to 152.80 $\mu\text{g}/\text{m}^3$ on 30th September. The graph of PM_{10} has fluctuated dramatically in this month where the activity at the construction site was heavy and fewer rain downpours at construction. The dry soil on site, makes the PM_{10} easily emitted with the movement of vehicles and other machinery operating at the research site. There are 13 value PM_{10} concentration in September that exceed Malaysia Ambient Air Quality Standard.

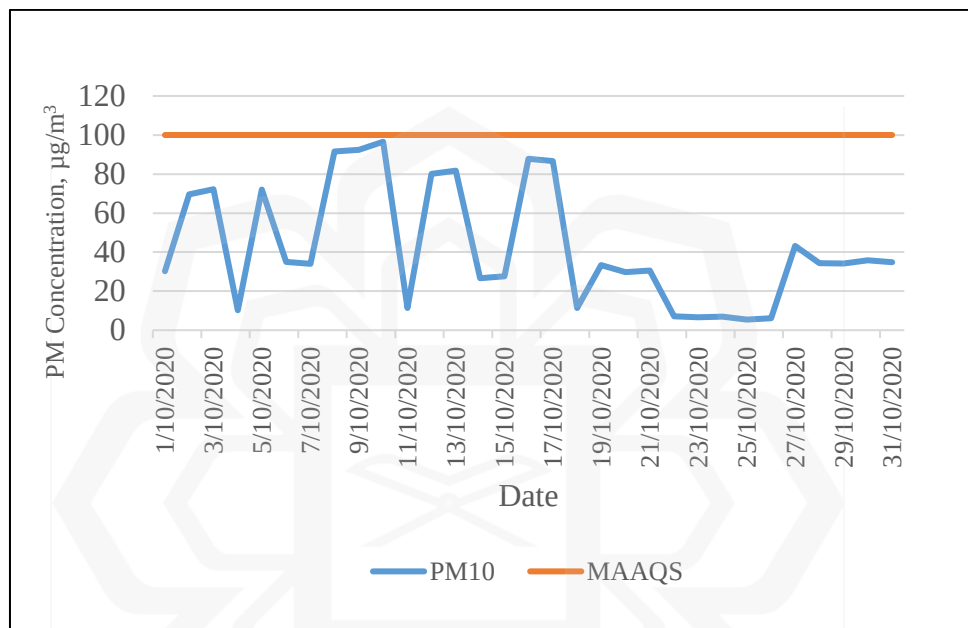


Figure 4.11 PM_{10} concentration in October 2020

The maximum value of 96.54 $\mu\text{g}/\text{m}^3$ and the minimum value of 5.43 $\mu\text{g}/\text{m}^3$ are shown in Figure 4.11 for October 2020. The graph starts at 30.16 $\mu\text{g}/\text{m}^3$ and increases until it reaches 72.25 $\mu\text{g}/\text{m}^3$. The PM_{10} concentration starts to decrease and sharply increase to reach 72.10 $\mu\text{g}/\text{m}^3$ on 5th October. The graph continues to fluctuate and reaches the highest point on 10th October with 96.54 $\mu\text{g}/\text{m}^3$ but continues to drop again on the next day. The graph increases on 12th and 13th with 80.02 $\mu\text{g}/\text{m}^3$ and 81.67 $\mu\text{g}/\text{m}^3$ respectively. However, the graph continued to decrease on the 14th and 15th of October but rocketed on the 16th of October with 87.87 $\mu\text{g}/\text{m}^3$. The graph drops again on 18th October with 11.36 $\mu\text{g}/\text{m}^3$ but rises to 33.40 $\mu\text{g}/\text{m}^3$ on 19th October. The graph continues to drop from 22nd to 26th October with the lowest point 5.43 $\mu\text{g}/\text{m}^3$. Still, the graph rises on 27th October to 43.22 $\mu\text{g}/\text{m}^3$ and the graph is gradually stable until the end of the

month. The activities at the construction are active and many particulates generate during this month. The PM₁₀ concentration in October are within the Malaysia Ambient Air Quality Standard.

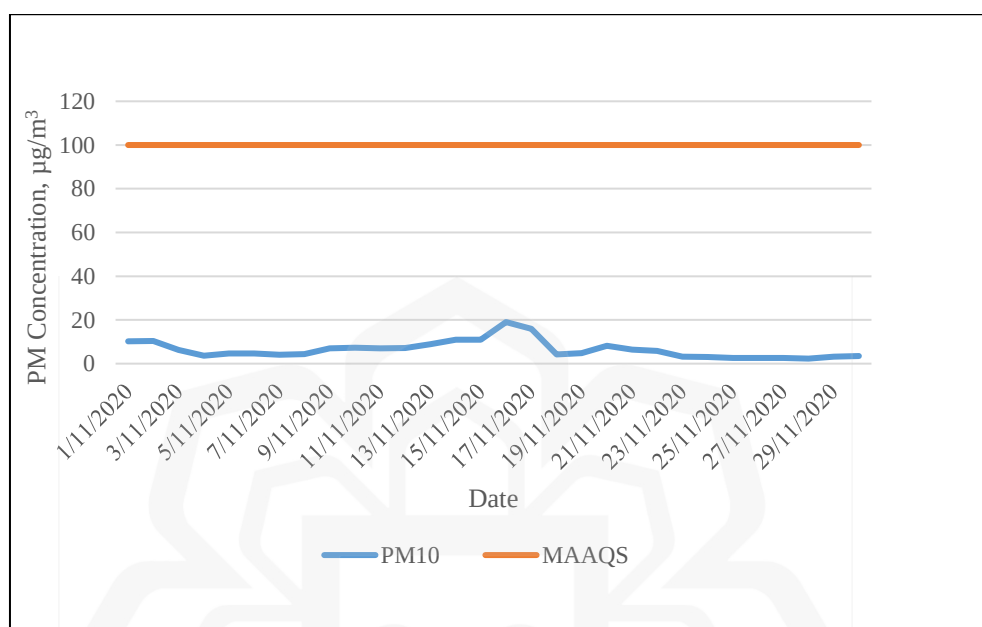


Figure 4.12 PM₁₀ concentration in November 2020

Figure 4.12 shows the maximum value of 19.00 µg/m³ and the minimum value of 2.28 µg/m³ in November 2020. The graph starts with 10.22 µg/m³ on the 1st of November but it drops on the 3rd of November and continues falling until the 8th of November with 4.28 µg/m³. Nevertheless, the graph starts to gradually increase from 9th November with 6.92 µg/m³ to 10.94 µg/m³ on 15th November. The graph rises to 19.00 µg/m³ on 16th November and slightly drops on 17th November 2020 with 15.90 µg/m³. The graph continues to drop to 4.76 µg/m³ on 19th November and increases to 6.43 µg/m³ on 21st November. However, the graph started to decline from 21st November to 30th November 2020 with the lowest point of 2.29 µg/m³ on 28th November. During this month, the construction site experienced rainy days and most of the construction activities had to be stopped or slowed down. The PM₁₀ concentration in November are within the Malaysia Ambient Air Quality Standard.

4.5.3 Cumulative PM_{2.5} and PM₁₀ Mass Concentration

The combination particulate matter for the six-month monitoring period shown in Figure 4.13. The pattern of the graph showed steady in the first and second months of the monitoring but then it started to increase in August. A tremendous graph pattern of PM_{2.5} showed in September 2020 and October 2020 where the PM_{2.5} exceeded the New Malaysia Ambient Air Quality Standard 2020 that it should not be more than 35 $\mu\text{g}/\text{m}^3$ 24-hour average. The high PM_{2.5} concentration may be due to high activity occurring such as movement of the lorry, filling, and levelling at the site. With less rain and less humidity, PM_{2.5} is easily emitted into the atmosphere.

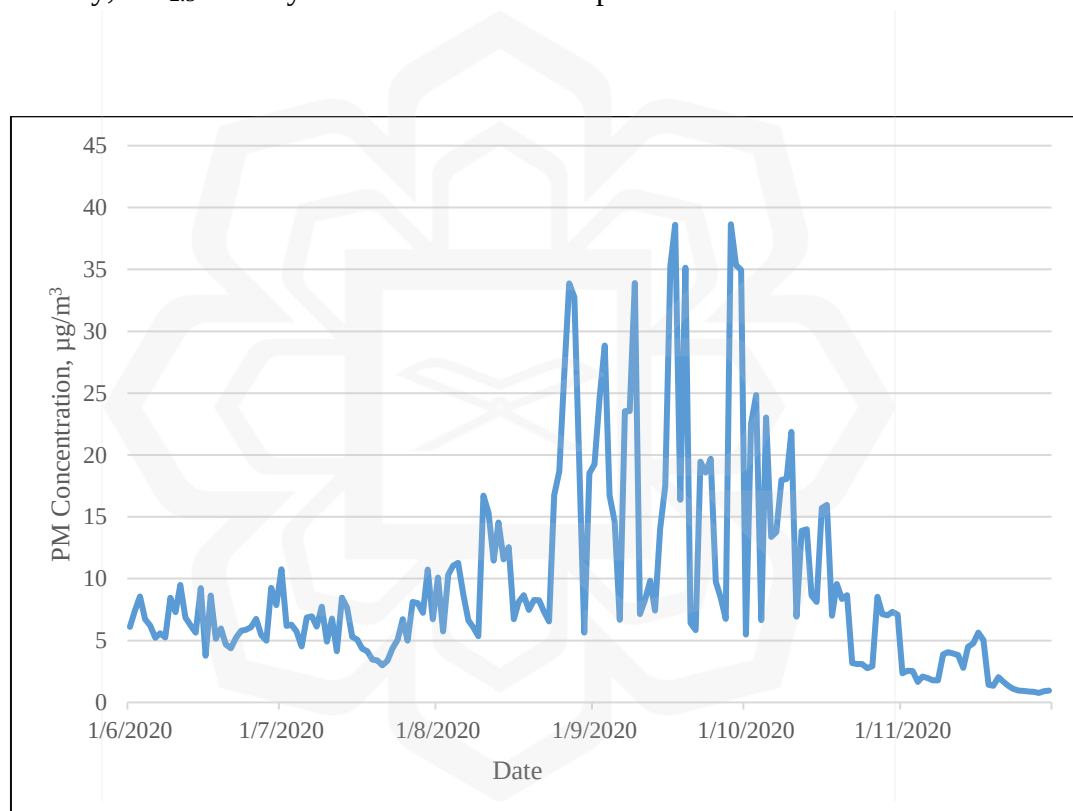


Figure 4.13 Cumulative PM_{2.5} concentration for 6-month monitoring

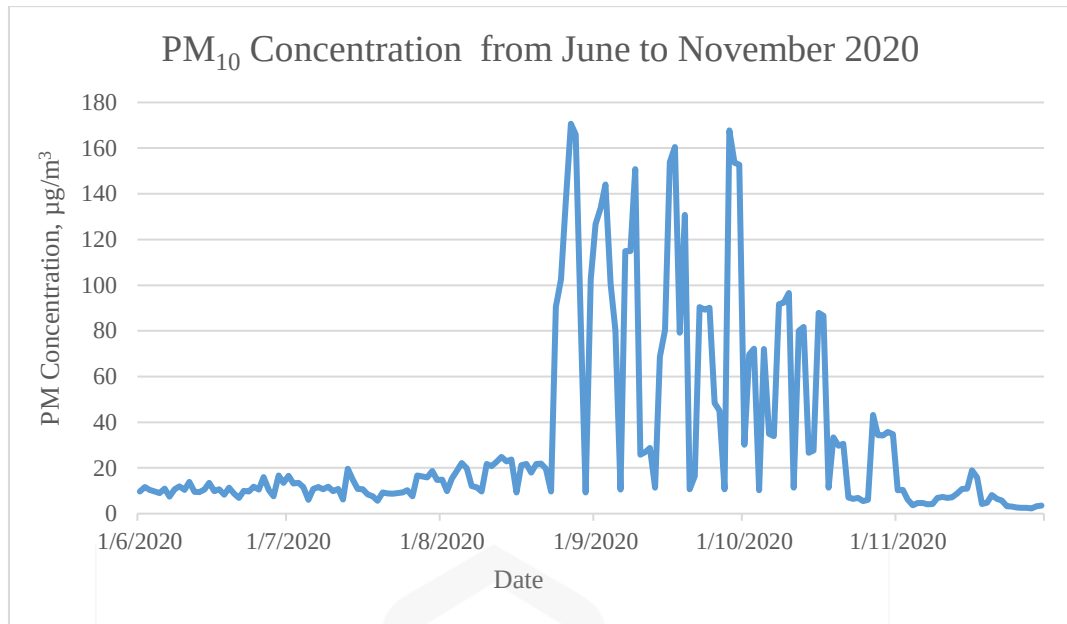


Figure 4.14 Cumulative PM₁₀ concentration for 6-month monitoring

Figure 4.14 shows the combination of the PM₁₀ concentration from June to November 2020. The pattern is very similar to the PM_{2.5} concentration. There is no significant variation in the measured PM concentration using the equipment. The source of pollution and meteorological conditions are from the same activities and within the same range period.

4.6 RESULT OF METEOROLOGY DATA

Meteorological data is important data that is used for current and future quantitative prediction and weather forecasting. Meteorological data is also used by the developer in organizing work activities at the construction site. It helps the management to plan the progress of work more efficiently. In this explanation, temperature, humidity, precipitation, wind direction, and wind speed factor will be explained together in their relationship that affects the distribution of PM_{2.5} at the construction site. However, the temperature, humidity, precipitation, wind speed, and wind direction have a great influence on the construction activities schedule that may cause delay in work progress and monthly target. The meteorological factor may also alternate the condition of the

soil which causes soil structure loss and a change in soil texture where the soil become muddy.

4.6.1 Temperature

The temperature from June 2020 to November 2020 is within the range of 24.1°C to 29.8°C (75 °F-84°F) respectively (Table 4.6). The temperature is normally high and stable during the monitoring for the 6 months. In June 2020, the mean temperature was 27.62°C while the minimum temperature was 26°C and the maximum temperature was 28.6°C. In July, the mean temperature is 27.4°C whereas the minimum temperature is 25.3°C and the maximum temperature is 28.4°C. In August 2020, the mean temperature was 28.1°C while the minimum temperature was 25.6°C and the maximum temperature was 29.8°C. The mean temperature for September is 27.6°C whereas the minimum temperature is 25.8°C and the maximum temperature is 28.9°C. In October, the mean temperature is 27.9°C whereas the minimum temperature is 26.7°C and the maximum is 29.3°C. For November, the mean temperature is 26.3°C while the minimum temperature is 24.1°C and the maximum temperature is 27.9°C.

The distance of the research site from the sea is 4.8 km. the distance is quite near and the heat is due to the presence of the sea. The heat above the sea heated up as the sea acts as a heat reservoir which warms the coastal area and surrounding area. Therefore, the temperature is normal and it is uniform temperature throughout the study. But in November, the minimum temperature is lower than in other months as it changes in temperature during monsoon season. Figure 4.15 shows the temperature graph plotted from June to November 2020.

Table 4.6 Summarization of temperature for 6-month monitoring

Month	Min (°C)	Max (°C)	Mean (°C)
June	26	28.6	27.6
July	25.3	28.4	27.4
August	25.6	29.8	28.1
September	25.8	28.9	27.6
October	26.7	29.3	27.9
November	24.1	27.9	26.3

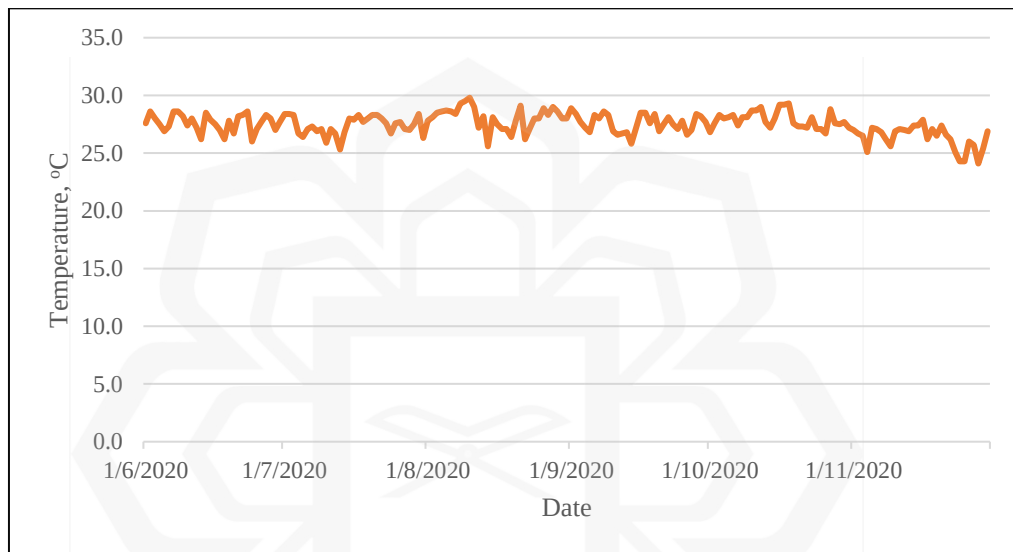


Figure 4.15 Temperature from June to November 2020

4.6.2 Humidity

The summarization of humidity was shown in Table 4.7. The relative humidity value at the construction site is between 75.1% to 93.2 %. The humid environment condition was due to the monsoon season, the location of the construction site's proximity to the sea, and our country has tropical climate. The mean humidity is 82% for this six-month monitoring. Below is the table of humidity from June to November 2020. From Table 4.3, we can define that the high relative humidity was in June, July, and November 2020. In November, the minimum relative humidity and the maximum are the highest within six-month with 81.4% and 93.2% respectively. In June the minimum relative humidity value is 79.1% and the maximum value is 89.5% while in July the minimum relative humidity value is 79.4% and the maximum value is 92.6%. %). August,

September and October showed slightly lower humidity in that particular month. In August, the minimum relative humidity value is 75.1% and the maximum value is 86.8%. In September, the minimum relative humidity value is 75.4% and the maximum value is 85.1% while in October the minimum relative humidity value is 75.4% and the maximum value is 85.7%.

Figure 4.16 shows the pattern distribution of humidity from June to November 2020. The graph showed a steady state from June to July. The graph slightly decreases and continues steadily from August till October. At the end of October, the graph gradually increases until the end of November. The humidity graph consists of a polynomial trendline that also includes the equation for the trendline (y) and the coefficient of determination (R^2).

Table 4.7 Summarization of humidity for 6-month monitoring.

Month	Minimum (RH%)	Maximum (RH%)	Mean (RH%)
June	79.1	89.5	84.3
July	79.4	92.6	83.3
August	75.1	86.8	80.5
September	75.4	85.1	80.6
October	75.4	85.7	80.5
November	81.4	93.2	86.5

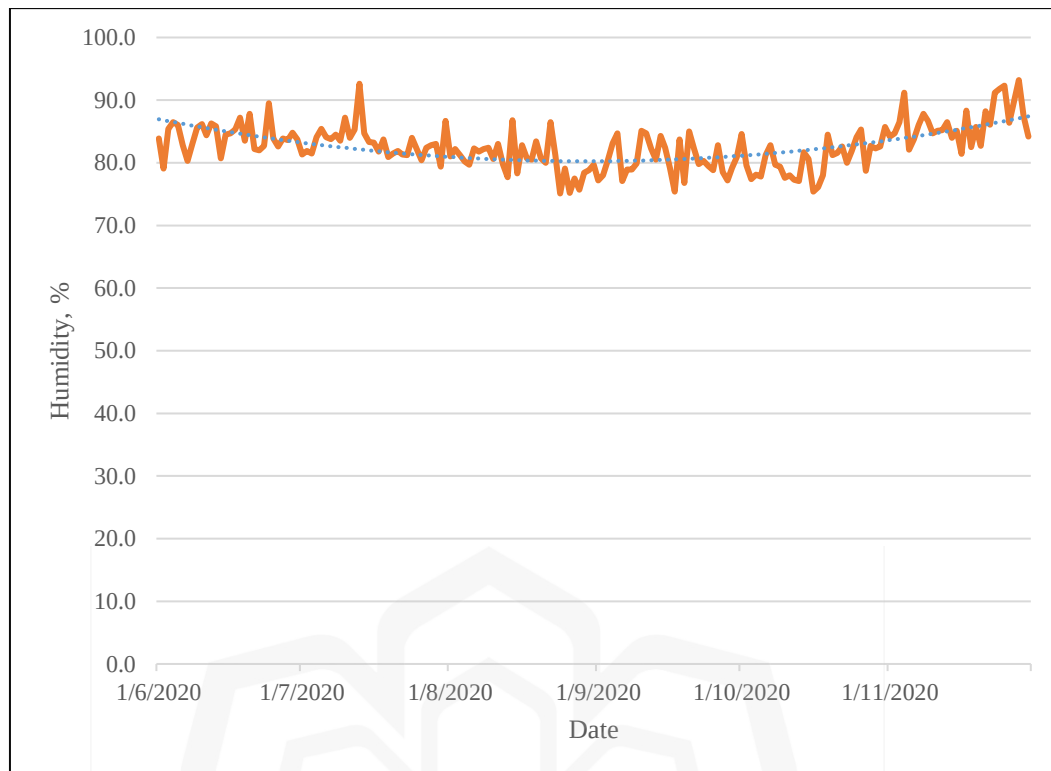


Figure 4.16 Humidity from June to November 2020

4.6.3 Rainfall

Table 4.8 shows the monthly average rainfall from June to November 2020. The highest average rainfall is in November 2020 with 14.3 mm and the lowest average rainfall is in September with 2.6 mm. Figure 4.17 shows the bar chart in June, the average rainfall is 9.2mm and in July is 8.4mm. The following month, the bar chart decreased to 3.7mm, 2.6 mm, and 3.4 mm in August, September and October respectively. However, in November the average rainfall increases to 14.3 mm. In October and November, Kuantan will face the monsoon season or rainy season. The volume (mm) of rain will increase and the weather will be rough throughout the month.

Table 4.8 Average rainfall (mm) for month 6-month monitoring

Month	Average rainfall (mm)
June	9.2
July	8.4
August	3.7
September	2.6
October	3.4
November	14.3

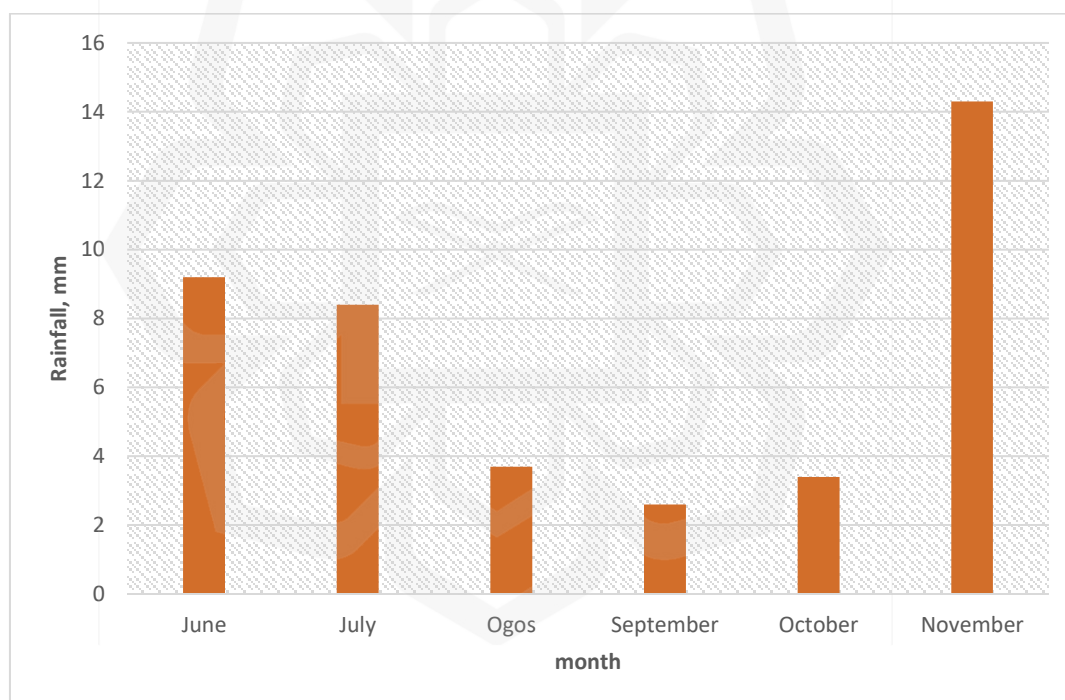


Figure 4.17 Average precipitation from June to November 2020

Table 4.9 shows the summarization of mean temperature, minimum and maximum temperature, rainfall (mm), and mean relative humidity (%). Malaysia has a tropical climate, therefore the temperature and humidity have relatively little seasonal and relatively constant for precipitation. The hot and rainy weather throughout the year makes the change in humidity not too big or too small.

Table 4.9 Summarization of mean temperature, minimum and maximum temperature, rainfall (mm), and mean relative humidity (%).

	June 2020	July 2020	August 2020	September 2020	October 2020	November 2020
Mean temperature, °C	6.47	6.04	12.58	19.51	10.86	2.34
Min. Temperature, °C	3.78	3.01	5.34	5.83	2.76	0.76
Max. Temperature, °C	9.50	10.77	33.89	38.65	24.85	5.65
Rainfall (mm)	9.2	8.4	3.7	2.6	3.4	14.3
Mean Relative Humidity (%)	84.3	83.3	80.5	80.6	80.5	86.5

4.6.4 Wind Direction and Wind Speed

Figure 4.18 shows the wind speed and wind direction in the Kuantan region within 6 month period from June to November 2020. About 56.17% wind direction with wind speed within 0.5-2.10 m/s (orange), 13.87% wind direction with wind speed within 2.10-3.60 m/s (yellow), 2.5% wind direction with wind speed within 3.60-5.70 m/s and 0.2% wind direction with wind speed more than 5.70 m/s. The calm wind is 27.25% of the time. The result of wind direction was obtained from the WRPLOT Software.

The wind speed and wind direction information were summaries using the WRPLOT software shown in the form of a wind rose diagram. The wind rose diagram is an isopleth diagram that provides the percentage and frequency of wind from a different direction. Figure 4.18 shows the wind rose blow from June to November 2020. Table 4.6 shows the 6-month monitoring period the wind blew from the South (S) 15% of the time, 9.2% wind blew from the South-Southwest (SSW) of the time, 8.6% wind blew from the North (N) of the time, 7.7% wind blew from North-Northwest (NNW) of the time while other wind which less than 5.0% wind blew from any direction of the time.

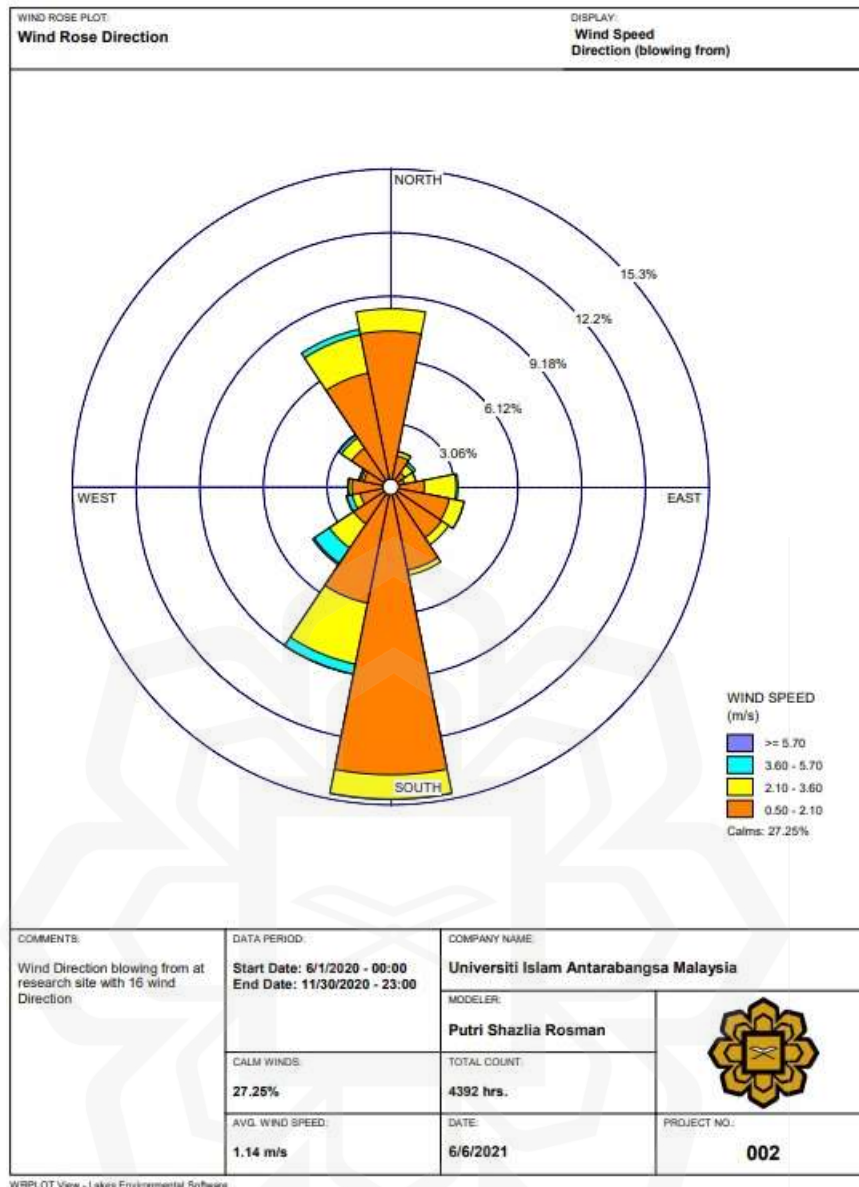


Figure 4.18 Wind rose (blowing) from 1st June 2020 until 30th November 2020

The legend on the right below shows the wind speed in meters per second (m/s) in four (4) different colours. Each colour presents the wind speed and it is shown as spoken in the wind diagram. The longest spoke shows the wind blew from the South at speeds between 0.5-2.10 m/s (orange) about 13.8% of the time, 2.10 – 3.60 m/s (yellow) about 1.2% of the time and 3.60 -5.70 m/s (light blue) about 0.02% of the time. The second spoke shows the wind blew from South-Southwest at speeds between 0.5- 2.10 m/s (orange) about 5.7% of the time, 2.10 – 3.60 m/s (yellow) about 3.0% of the time, 3.60 – 5.70 m/s (light blue) about 0.5% of the time and more than 5.7 m/s (purple) about 0.02% of the time. The third spoke shows the wind blew from the North at speeds

between 0.5 – 2.10 m/s (orange) about 7.5% of the time and 2.10 – 3.60 m/s (yellow) about 1.1% of the time. The fourth spoke shows the wind blew from the North-Northwest at speeds between 0.5 -2.10 m/s (orange) about 5.6% of the time, 2.10-3.60 m/s (yellow) about 1.9% of the time and 3.60 – 5.70 m/s (light blue) about 0.3% of the time. The calm wind is 27.25% of the time. Table 4.10 below shows the summarization of wind direction and wind classes for the past 6-month monitoring.

Table 4.10 Summarization of wind direction and wind classes (m/s)
for 6 months monitoring

Direction/ wind classes (m/s)	0.5 -2.10	2.10 - 3.60	3.60-5.70	>5.70	total
N	7.49	1.07	0.00	0.00	8.56
NNE	1.53	0.20	0.02	0.00	1.75
NE	0.82	0.46	0.16	0.00	1.43
ENE	0.66	0.57	0.02	0.00	1.25
E	1.62	1.53	0.09	0.00	3.23
ESE	2.87	0.71	0.02	0.00	3.60
SE	2.94	0.41	0.00	0.00	3.35
SSE	4.08	0.25	0.00	0.00	4.33
S	13.82	1.16	0.02	0.00	15.00
SSW	5.69	2.98	0.48	0.02	9.18
SW	2.14	1.39	0.89	0.09	4.51
WSW	1.50	0.39	0.25	0.05	2.19
W	1.87	0.16	0.02	0.02	2.07
WNW	1.32	0.14	0.09	0.02	1.57
NW	2.25	0.59	0.16	0.00	3.01
NNW	5.58	1.87	0.27	0.00	7.72
Sub total	56.17	13.87	2.50	0.21	72.75
calms	27.25				
Total	100				

Figure 4.19 shows in June 2020, the wind blew from the South (S) 15.8% of the time, 11.5% wind blew from the South-Southwest (SSW) of the time, 5.8% wind blew from the North-Northwest (NNW) of the time, 5.3% wind blew from North (N) of the time while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the South at speeds between 0.5-2.10 m/s

(orange) about 15.1% of the time and 2.10 – 3.60 m/s (yellow) about 0.7% of the time. The second spoke shows the wind blew from South-Southwest at speeds between 0.5- 2.10 m/s (orange) about 7.4% of the time, 2.10 – 3.60 m/s (yellow) about 3.6% of the time, 3.60 – 5.70 m/s (light blue) about 0.4% of the time and more than 5.7 m/s (purple) about 0.1% of the time. The third spoke shows the wind blew from the North-Northwest (NNW) at speeds between 0.5 – 2.10 m/s (orange) about 5.0% of the time and 2.10 – 3.60 m/s (yellow) about 0.7% of the time and 3.60 – 5.70 m/s (light blue) about 0.1% of the time. The fourth spoke shows the wind blew from the North at speeds between 0.5 -2.10 m/s (orange) about 5.0% of the time and 2.10- 3.60 m/s (yellow) about 0.3% of the time. The calm wind is 29.17% of the time.

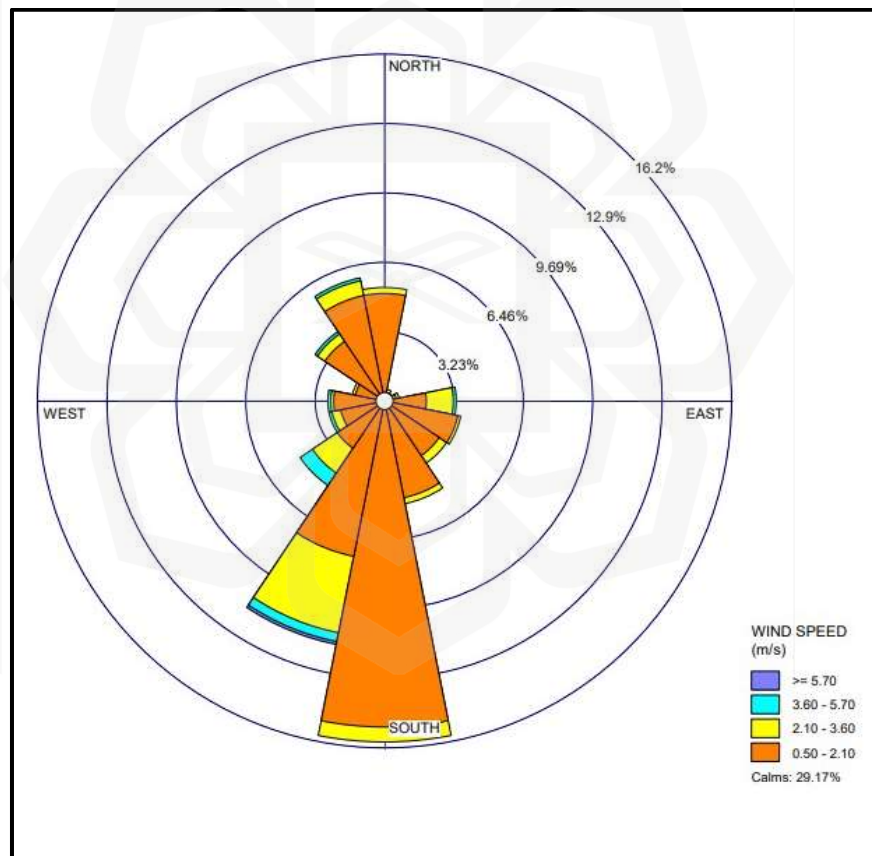


Figure 4.19 Wind rose in June 2020

Figure 4.20 shows in July 2020, the wind blew from the South (S) 16.3% of the time, 7.5% wind blew from the South-Southwest (SSW) of the time, 5.8% wind blew from the North-Northwest (NNW) of the time, 5.4% wind blew from North (N) of the

time, 5.2% wind blew from South-Southeast (SSE) and North (N) of the time, while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the South at speeds between 0.5-2.10 m/s (orange) about 15.2% of the time and 2.10 – 3.60 m/s (yellow) about 1.1% of the time. The second spoke shows the wind blew from South-Southwest at speeds between 0.5- 2.10 m/s (orange) about 5.0% of the time, 2.10 – 3.60 m/s (yellow) about 2.4% of the time and 3.60 – 5.70 m/s (light blue) about 0.1% of the time. The third spoke shows the wind blew from the North-Northwest (NNW) at speeds between 0.5 – 2.10 m/s (orange) about 4.7% of the time, 2.10 – 3.60 m/s (yellow) about 0.5% of the time and 3.60 – 5.70 m/s (light blue) about 0.1% of the time. The fourth spoke shows the wind blew from the South-Southeast (SSE) at speeds between 0.5 -2.10 m/s (orange) about 4.8% of the time and 2.10- 3.60 m/s (yellow) about 0.4% of the time. The fifth spoke shows the wind blew from the North at speeds between 0.5 -2.10 m/s (orange) about 4.5% of the time and 2.10- 3.60 m/s (yellow) about 0.7% of the time. The calm wind is 32.8% of the time.

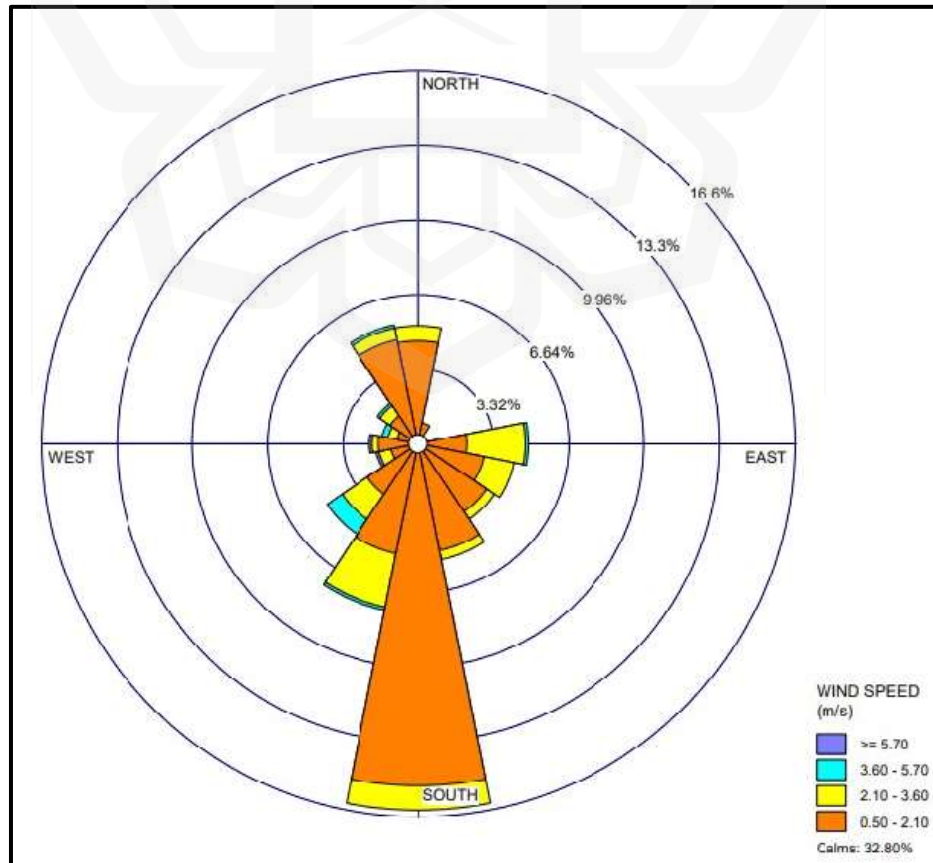


Figure 4.20 Wind rose in July 2020.

Figure 4.21 shows in August 2020, the wind blew from the South (S) 20.8% of the time, 10.6% wind blew from the South-Southwest (SSW) of the time, 6.5% wind blew from the East-Southeast (ESE) of the time, 5.2% wind blew from Southeast (SE) of the time, while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the South at speeds between 0.5- 2.10 m/s (orange) about 19.0% of the time and 2.10 – 3.60 m/s (yellow) about 1.9% of the time. The second spoke shows the wind blew from South-Southwest (SSW) at speeds between 0.5- 2.10 m/s (orange) about 7.0% of the time, 2.10 – 3.60 m/s (yellow) about 3.4% of the time and 3.60 – 5.70 m/s (light blue) about 0.3% of the time. The third spoke shows the wind blew from the East-Southeast (ESE) at speeds between 0.5 – 2.10 m/s (orange) about 5.5% of the time and 2.10 – 3.60 m/s (yellow) about 0.9% of the time. The fourth spoke shows the wind blew from the Southeast (SE) at speeds between 0.5 -2.10 m/s (orange) about 4.4% of the time and 2.10- 3.60 m/s (yellow) about 0.8% of the time. The calm wind is 30.0% of the time.

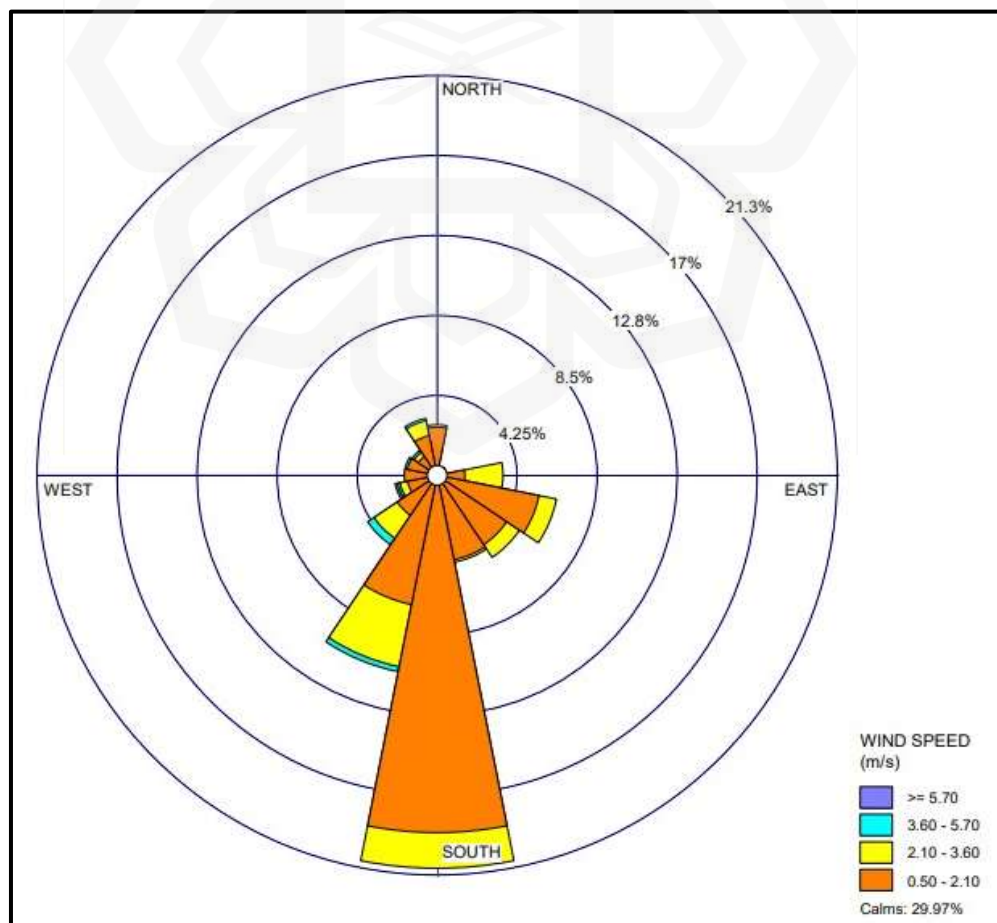


Figure 4.21 Wind rose in August 2020.

Figure 4.22 shows in September 2020, the wind blew from the South (S) 17.6% of the time, 13.1% wind blew from the South-Southwest (SSW) of the time, 6.9% wind blew from the Southwest (SW) of the time, 5.4% wind blew from South-Southeast (SSE) of the time, while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the South (S) at speeds between 0.5-2.10 m/s (orange) about 16.1% of the time, 2.10 – 3.60 m/s (yellow) about 1.4% of the time and 3.60 – 5.70 m/s (light blue) about 0.1% of the time. The second spoke shows the wind blew from South-Southwest (SSW) at speeds between 0.5- 2.10 m/s (orange) about 6.9% of the time, 2.10 – 3.60 m/s (yellow) about 4.6% of the time and 3.60 – 5.70 m/s (light blue) about 1.5% of the time. The third spoke shows the wind blew from the Southwest (SW) at speeds between 0.5 – 2.10 m/s (orange) about 1.8% of the time, 2.10 – 3.60 m/s (yellow) about 2.6% of the time, 3.60 – 5.70 m/s (light blue) about 2.2% of the time and more than 5.70 m/s (purple) about 0.3% of the time. The fourth spoke shows the wind blew from the South-Southeast (SSE) at speeds between 0.5 -2.10 m/s (orange) about 5.1% of the time and 2.10- 3.60 m/s (yellow) about 0.3% of the time. The calm wind is 26.8% of the time

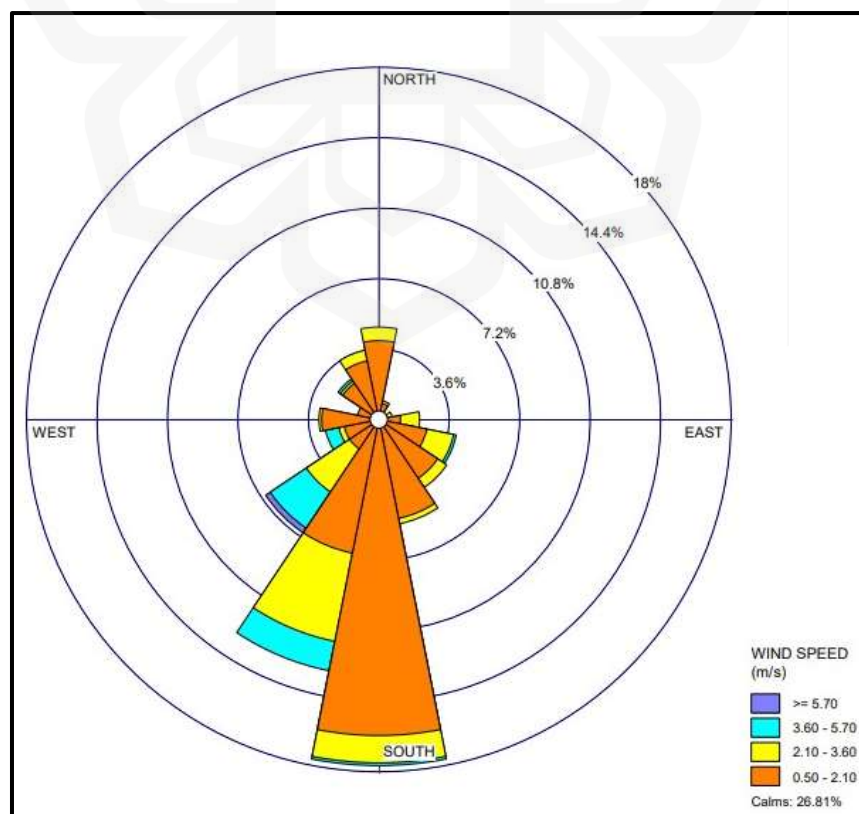


Figure 4.22 Wind rose in September 2020.

Figure 4.23 show in October 2020, the wind blew from the South (S) 16.9% of the time, 11.2% wind blew from the South-Southwest (SSW) of the time, 9.9% wind blew from the North (N) of the time, 9.3% wind blew from North-Northwest (NNW) of the time, 5.1% wind blew from Southwest (SW) of the time, while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the South (S) at speeds between 0.5-2.10 m/s (orange) about 15.0% of the time and 2.10 – 3.60 m/s (yellow) about 1.9% of the time. The second spoke shows the wind blew from South-Southwest (SSW) at speeds between 0.5- 2.10 m/s (orange) about 7.1% of the time, 2.10 – 3.60 m/s (yellow) about 3.5% of the time and 3.60 – 5.70 m/s (light blue) about 0.5% of the time. The third spoke shows the wind blew from the North (N) at speeds between 0.5 – 2.10 m/s (orange) about 9.4% of the time and 2.10 – 3.60 m/s (yellow) about 0.5% of the time. The fourth spoke shows the wind blew from the North-Northwest (NNW) at speeds between 0.5 -2.10 m/s (orange) about 7.3% of the time, 2.10- 3.60 m/s (yellow) about 1.2% of the time and 3.60 – 5.70 m/s (light blue) about 0.8% of the time. The fifth spoke shows the wind blew from the Southwest (SW) at speeds between 0.5 -2.10 m/s (orange) about 2.4% of the time, 2.10- 3.60 m/s (yellow) about 1.2% of the time, 3.60 – 5.70 m/s (light blue) about 1.2% of the time and more than 5.7 m/s (purple) about 0.3% of the time. The calm wind is 23.5% of the time.

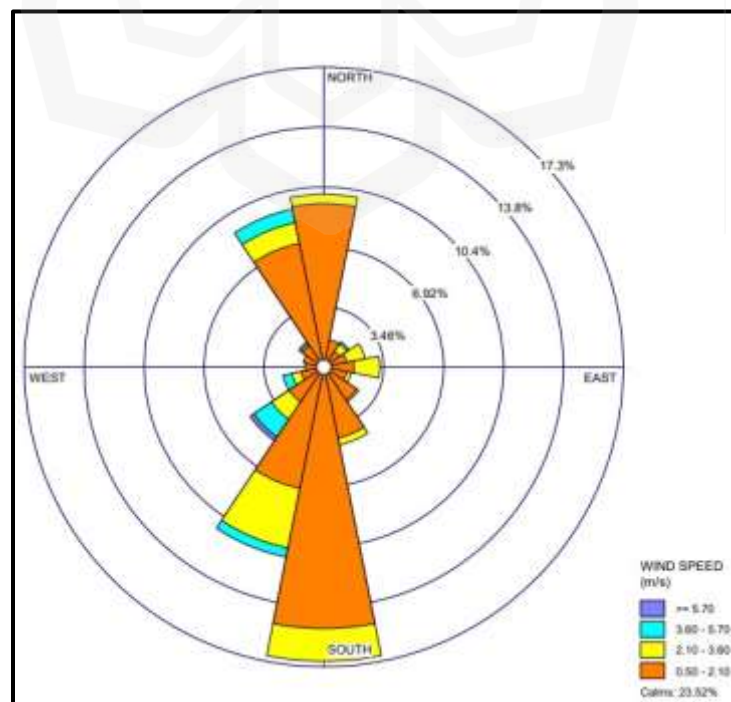


Figure 4.23 Wind rose in October 2020

Figure 4.24 shows in November 2020, the wind blew from the North (N) 23.8% of the time, 19.3% wind blew from the North-Northwest (NNW) of the time, 6.3% wind blew from the Northwest (NW) of the time, 6.1% wind blew from North-Northeast (NNE) of the time, 5.1% wind blew from Northeast (NE) of the time, while other wind which less than 5.0% wind blew from any direction of the time. The longest spoke shows the wind blew from the North (N) at speeds between 0.5-2.10 m/s (orange) about 19.6% of the time and 2.10 – 3.60 m/s (yellow) about 4.2% of the time. The second spoke shows the wind blew from North-Northwest (NNW) at speeds between 0.5- 2.10 m/s (orange) about 11.4% of the time, 2.10 – 3.60 m/s (yellow) about 7.5% of the time and 3.60 – 5.70 m/s (light blue) about 0.4% of the time. The third spoke shows the wind blew from the Northwest (NW) at speeds between 0.5 – 2.10 m/s (orange) about 3.9% of the time, 2.10 – 3.60 m/s (yellow) about 2.1% of the time and 3.60 – 5.70 m/s (light blue) about 0.3% of the time. The fourth spoke shows the wind blew from the North-Northeast (NNE) at speeds between 0.5 -2.10 m/s (orange) about 5.0% of the time, 2.10- 3.60 m/s (yellow) about 1.0% of the time and 3.60 – 5.70 m/s (light blue) about 0.1% of the time. The fifth spoke shows the wind blew from the Northeast (NE) at speeds between 0.5 -2.10 m/s (orange) about 2.5% of the time, 2.10- 3.60 m/s (yellow) about 1.8% of the time and 3.60 – 5.70 m/s (light blue) about 0.8% of the time. The calm wind is 21.1% of the time.

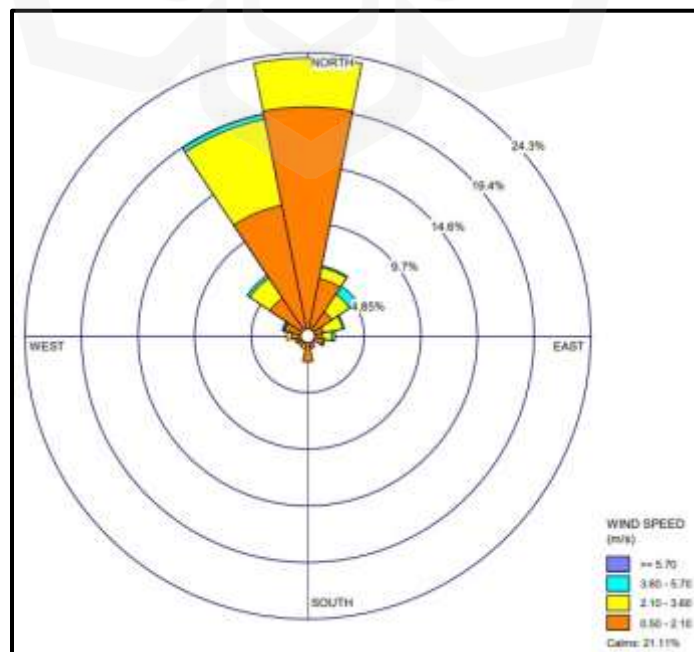


Figure 4.24 Wind rose in November 2020

4.7 RESULT ON PM_{2.5} PATTERN DISTRIBUTION RSTUDIO

The raw data of PM_{2.5} were analysed using the RStudio software and the R **openair** package. The result from the analysis is in the form of pollution rose. Pollution rose is a diagram of the pollutant concentration carried by the variant wind that passes through the project site. The frequency of count by wind direction is the radial frequency given in percentage. The wind direction that passes the project site is shown in petals. The wind direction is where the pollution will be brought to. The colour coded in the form of rose “petals” represents the various PM_{2.5} concentrations. The pollution rose in R studio used **pollutionRose** function in **openair**;

```
pollutionrose (data set, pollutant = “type of air pollutant”)
```

Table 4.11 shows the wind speed and wind direction using R studio software. The most frequent wind direction is from South-Southwest (SSW) with less than 24% of the frequency of count by wind direction, followed by the East (E) with less than 18% frequency of count by wind direction, followed by both Southwest (SW) and North-Northwest (NNW) less than 13% frequency of count by wind direction. The wind from Northeast (NE) less than 8% frequency of count by wind direction, wind from Southeast (SE) less than 5% frequency of count by wind direction, wind from North (N), East-Southeast (ESE), Southeast (SE) and South(S) about less than 4% frequency of count by wind direction, wind from West (W) and Northwest (NW) about less than 3% frequency of count by wind direction and lastly, wind from North-northeast (NNE) and about less than 2% frequency of count by wind direction.

Table 4.11 Summarization of wind direction and wind speed using the R studio software.

PM _{2.5} Conc (µg/m ³) Wind Direction	Frequency of count by wind direction (%)					
	0 to 5	5 to 10	10 to 15	15 to 20	20 above	Total
SSW	3%	14%	1%	2%	4%	24%
SW	1%	4%	2%	3%	3%	13%
W	1%	1%	1%	0%	0%	3%
NW	2%	1%	0%	0%	0%	3%
NNW	6%	4%	2%	1%	0%	13%
N	1%	2%	1%	0%	0%	4%
NNE	1%	1%	0%	0%	0%	2%
NE	3%	4%	0%	0%	1%	8%
E	8%	6%	1%	2%	1%	18%
ESE	0%	2%	1%	1%	0%	4%
SE	1%	3%	1%	0%	0%	5%
S	1%	2%	1%	0%	0%	4%
Total	28%	44%	11%	9%	9%	100%

Figure 4.25 shows the pollution rose of PM_{2.5} concentration using the R Studio software. The wind from the South-Southwest carried a large contribution concentration of PM_{2.5} portion about 14% of 5 to 10 µg/m³ of PM_{2.5} (green) were carried out by wind followed by 4% of above 20 µg/m³ of PM_{2.5} (red), 3% of 0 to 5 µg/m³ of PM_{2.5} (purple), 2% of 15 to 20 µg/m³ of PM_{2.5} (orange), and 1% of 10 to 15 µg/m³ of PM_{2.5} (light yellow). The second highest wind is from the East showing about 8% of 0 to 5 µg/m³ of PM_{2.5} (purple) carried out by the wind followed by 6% of 5 to 10 µg/m³ of PM_{2.5} (green petal), 2 % of 15 to 20 µg/m³ of PM_{2.5} (orange), and 1% both 10 to 15 µg/m³ of PM_{2.5} (light yellow) and above 20 µg/m³ of PM_{2.5} (red). The third highest wind from Southwest (SW) and North-Northwest (NNW) carried out 13%. The Southwest wind about 4% of 5 to 10 µg/m³ of PM_{2.5}, 3% of 15 to 20 µg/m³ of PM_{2.5} and above 20 µg/m³ of PM_{2.5}, 2% of 10 to 15 µg/m³ of PM_{2.5} and 1% of 0 to 5 µg/m³ of PM_{2.5} while the North-Northwest wind about 6% of 0 to 5 µg/m³ of PM_{2.5}, 4% of 5 to 10 µg/m³ of PM_{2.5}, 2% of 10 to 15 and 1% of 15 to 20 µg/m³ of PM_{2.5}.

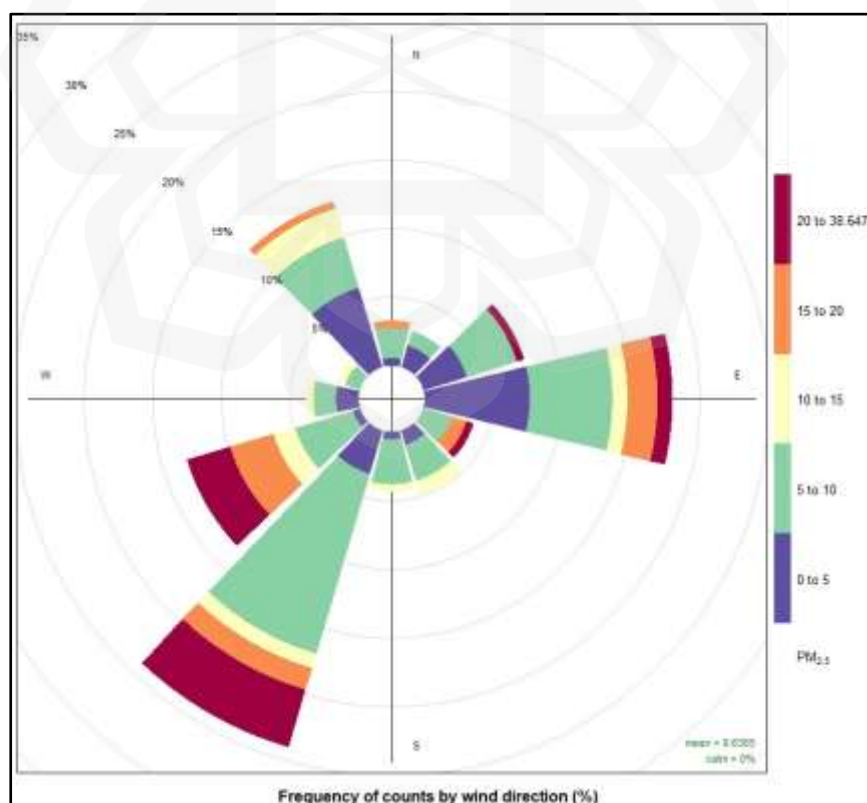


Figure 4.25 Monitoring of PM_{2.5} concentration (µg/m³) at the research site by wind direction using the R studio software. Each circle represents the frequency of count by wind direction (%).

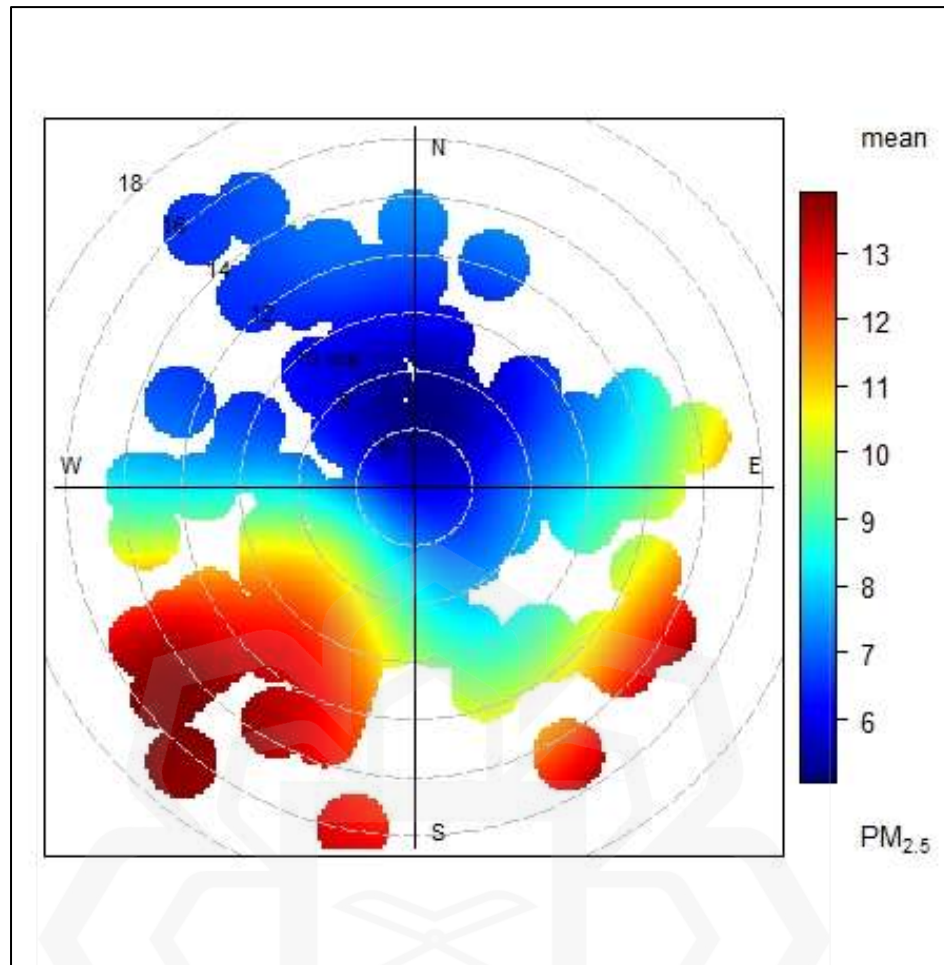


Figure 4.26 Bivariate polar showing the distribution of PM_{2.5} for 6-month monitoring, with wind speed m/s (radius of the circle) and wind direction from the construction site to the surrounding area.

Figure 4.26 shows the blue polar shows a large portion of the distribution PM_{2.5} in the Bivariate polar. About 0 to 8 µg/m³ of PM_{2.5} distributed to the North (N), Northwest (NW), Southwest (SE), and Northeast (NE) areas in the range of 4 m/s to 18 m/s within 6 months from June to November 2020. The light blue polar distributed in 3 directions East, West, and South in the range of 8 µg/m³ to 9 µg/m³ within 6 m/s to 14 m/s. The yellow-range polar distribute to East (E), West-Southwest (WSW), Southwest (SW), East-Southeast (ESE), and Southeast (SE) in the range of 10 µg/m³ to 11 µg/m³ within 7 m/s to 15 m/s. The red polar distribute to Southeast (SE), Southwest (SW), South-Southwest (SSW), and South-Southeast (SSE) in the range of 12 µg/m³ and above within 8 m/s to 18 m/s. The light blue polar shows the distribution of PM_{2.5} concentration between 8 µg/m³ to 9 µg/m³ to West (W), E (East), and South-Southeast (SSE) with windspeed between 2.1 m/s to 4.3 m/s. The yellow-orange polar shows the

distribution of PM_{2.5} concentration between 10 µg/m³ to 11 µg/m³ in Southwest (SW), Southeast (SE), and East (E) with windspeed between 1.43 m/s to 7.718 m/s.

4.8 CONCLUSION

The exposure to PM_{2.5} and PM₁₀ at the construction site had a statistically significant impact on the residential area and its surrounding area. The pattern distribution spread widely outside the construction site. Analysis data conducted throughout these 6 months shows that the spread of PM_{2.5} and PM₁₀ is occurring in the study area. Through data descriptive analysis the month of August and September are the months with the highest spread of PM_{2.5} and PM₁₀ emitted from the construction site. Based on meteorological data in August and September, this study area experienced a dry and less rainy season with a rainfall rate of only 3.7 mm and 2.6 mm in those months. Hot, dry conditions and less rain make construction activities very active and many movements involve the release of PM_{2.5} and PM₁₀ into the air. November shows a slight release of PM_{2.5} and PM₁₀ because that month experienced a high rate of rain which was 14.4 mm. Meteorological influence is seen to play an important role in the spread of PM_{2.5} and PM₁₀. The presence of wind velocity and direction helps in the spread of PM_{2.5} and PM₁₀ during hot and dry seasons

The use of WRPLOT in this study is very helpful in tracking the wind speed and direction that passes through the study area. However, the use of this wind data must use the latest and relevant data. The use of WRPLOT is very easy and user-friendly, but the data must make sure that every data entered into the data column is accurate and correct. Entering inaccurate and missing data will not produce the output as requested and this will make it difficult to analyze the data. The use of colour on the wind rose petal should also be chosen well so that the visual description can be delivered accurately.

Rstudio was very helpful in this study in producing a clear visual of PM_{2.5} dispersion. However, the visual spread of PM₁₀ was not implemented in this study using this software since the commuter had failed and had to be formatted for improvement. The use of Rstudio is seen to be able to compete with the use of environmental software

on the market with the production of easy-to-understand outputs. Rstudio is free and can be used by all walks of life. The drawback of using this Rstudio is that understanding the use of code and comment becomes a little difficult for those not interested in the code and comment system. It is very difficult to translate the coding that wants to be analysed and the confusion in choosing the right coding. The arrangement of raw data before export into Rstudio must follow the correct order and otherwise, the data cannot be processed and analyzed by the software.

There are many more software on the market now that can analyze environmental data well. The selection of software in the market should be according to suitability such as the cost of purchase and rental, the desired output, the simple procedure and the time-consuming process analysis. The sustainable development factor should also be applied in the use of this software where it helps in managing the business influence in reducing environmental pollution by managing the environmental in positive impact such as implementation of green strategies, environmental management system, and green supply chain management practices.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

All the results of the study will be explained to achieve the objectives of the study. The objective of the study should be clearly and precisely explained for better understanding. In addition to that, the research problems and research methods carried out are discussed in this chapter. From Chapter 4, many analysis results were found for this study. All results will be discussed clearly to answer the objectives of this study.

5.2 DISCUSSION OF FINDINGS

The research objectives of the study are to require the study to achieve its goals and the information presented is accurate and uses methods as discussed in this chapter.

5.2.1 RO1: Various Concentrations of PM_{2.5} Emitted from the Construction Site Activities

The static data collected from the research site will be summarised based on the actual situation, the influence of meteorological data and other factors that may affect PM_{2.5} and PM₁₀ emissions from the construction site. Through understanding the process of analysing data, the data able to identify the areas of strength and weakness in the research analysis.

- i. Analysis of data collection using meteorological software and environmental modelling.
- ii. Mapping the PM_{2.5} prediction dispersion on Google Earth for map visualization.
- iii. Gain recommendations and solutions from the research investigation done.

5.2.1.1 Mean

Refer to Table 4.1 Chapter 4, September stated the highest mean with $19.51 \mu\text{g}/\text{m}^3$ respectively followed by August with $12.59 \mu\text{g}/\text{m}^3$, the month of October with $10.86 \mu\text{g}/\text{m}^3$, slightly different in June and July with $6.47 \mu\text{g}/\text{m}^3$ and $6.04 \mu\text{g}/\text{m}^3$. The lowest mean was in November with $2.34 \mu\text{g}/\text{m}^3$ respectively. Mean is the ratio between the sum of monthly monitoring of $\text{PM}_{2.5}$ and the number of the monitoring $\text{PM}_{2.5}$ that have been carried out. Mean can be used as the centre of distribution of $\text{PM}_{2.5}$ and PM_{10} .

Figure 5.1 shows 47% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in September 2020 where a total of 14 days in September is above the mean level. Within 14 days the emission of $\text{PM}_{2.5}$ was higher than the mean rate compared to 16 days where the emission rate of $\text{PM}_{2.5}$ was low. Figure 5.2 shows 33% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in August 2020 where a total of 10 days in August is above the mean level. 10 days show that the emission of $\text{PM}_{2.5}$ was higher than the mean rate ($12.58 \mu\text{g}/\text{m}^3$).

Figure 5.3 shows 39% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in October 2020 where 12 days in October is above the mean level. Figure 5.4 shows 40% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in June 2020 where 12 days in June is above the mean level. Figure 5.5 shows 52% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in July 2020 where 16 days in July is above the mean level. Figure 5.6 shows 37% of $\text{PM}_{2.5}$ concentration above the mean value with error bars in November 2020 where a total of 11 days in November is above the mean level.

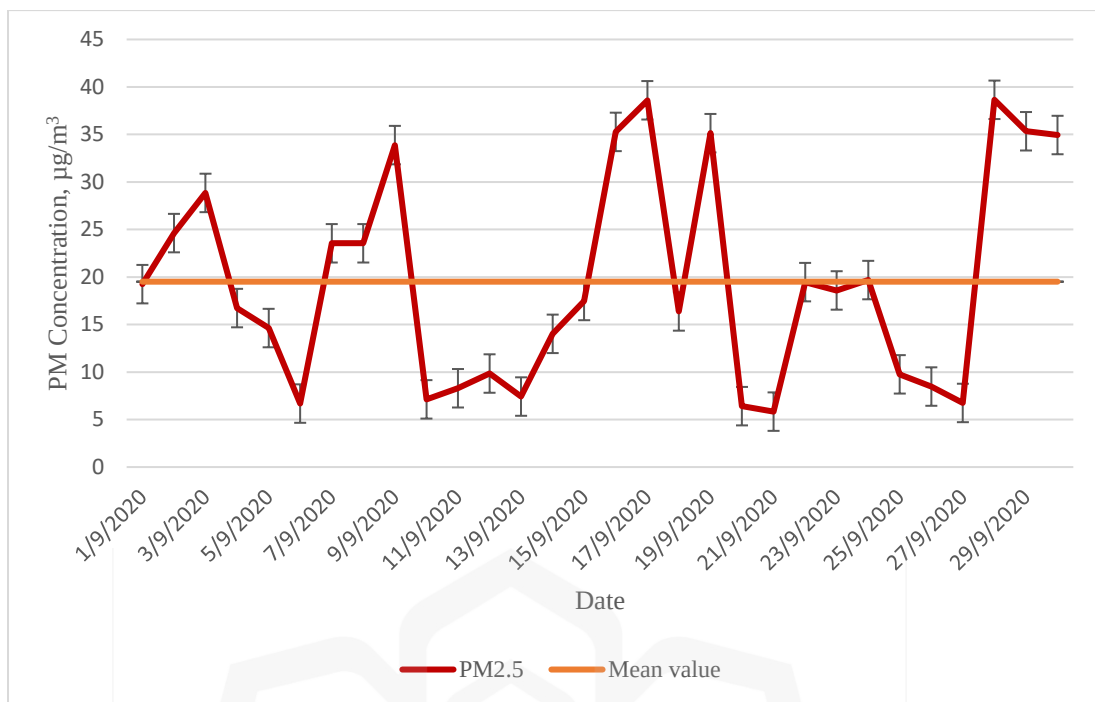


Figure 5.1 PM_{2.5} Concentration vs Mean of September 2020.

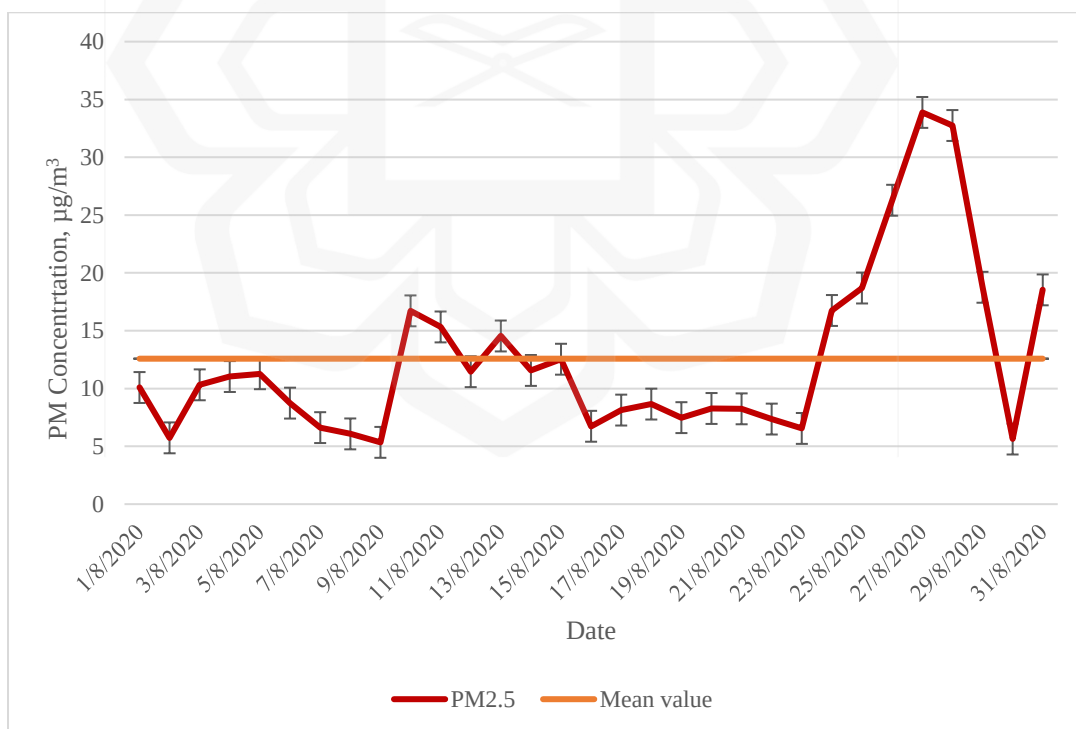


Figure 5.2 PM_{2.5} Concentration vs Mean of August 2020.

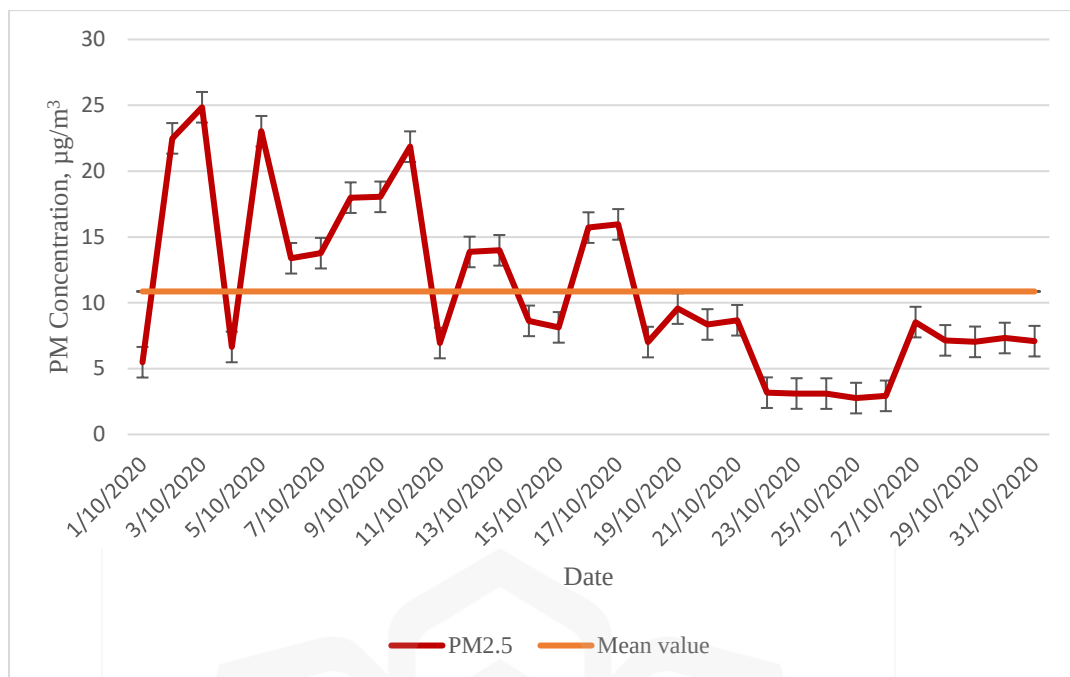


Figure 5.3 PM_{2.5} Concentration vs Mean of October 2020

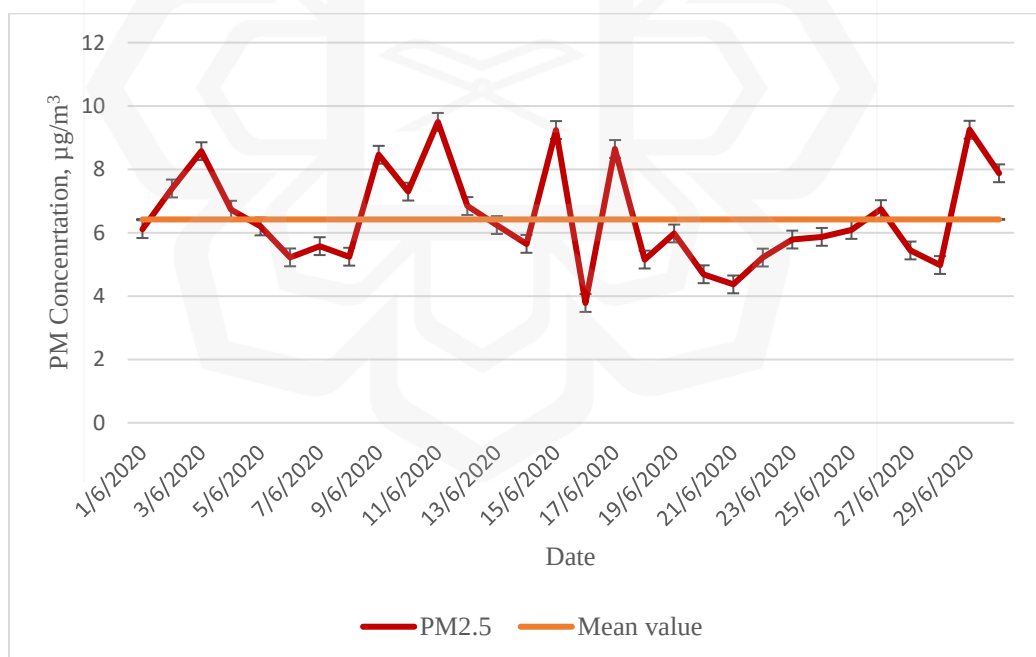


Figure 5.4 PM_{2.5} Concentration vs Mean of June 2020.

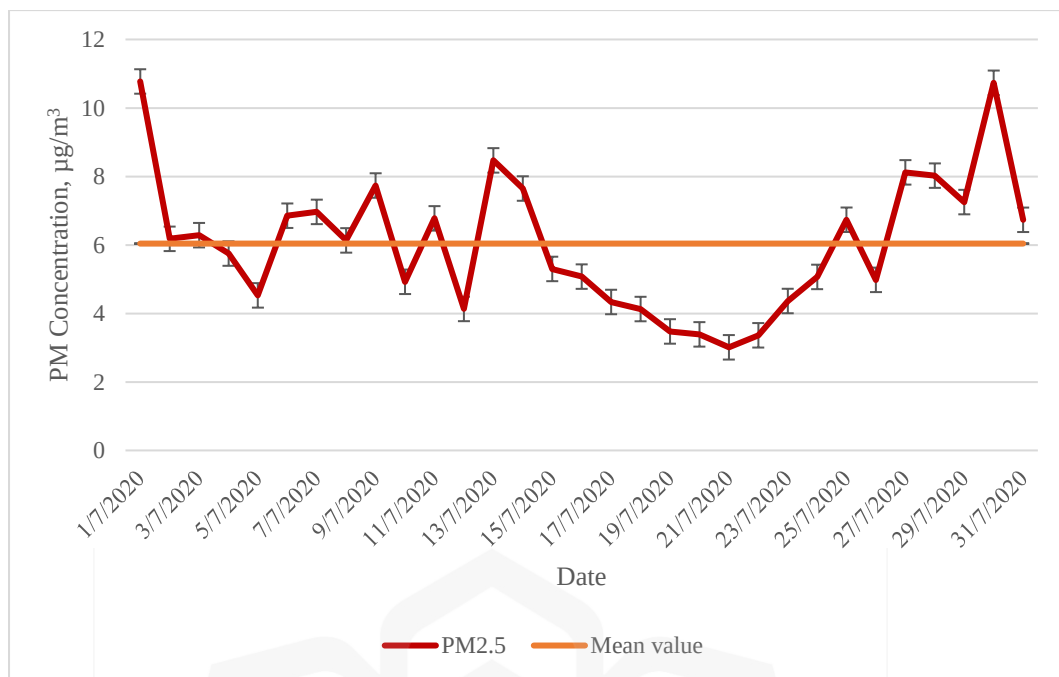


Figure 5.5 PM_{2.5} Concentration vs Mean of July 2020

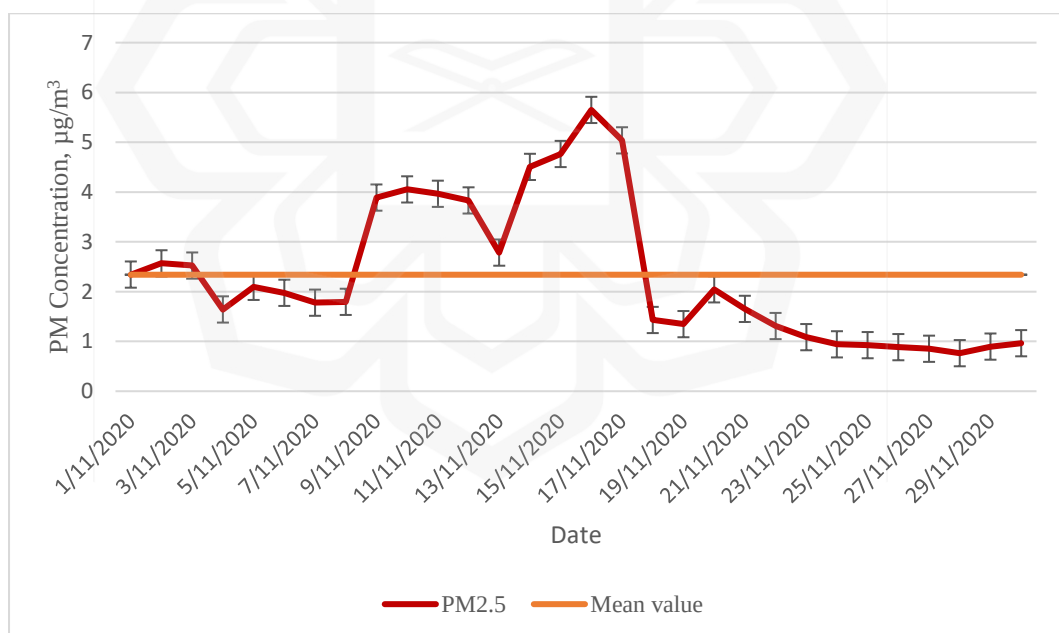


Figure 5.6 PM_{2.5} Concentration vs Mean of the November 2020

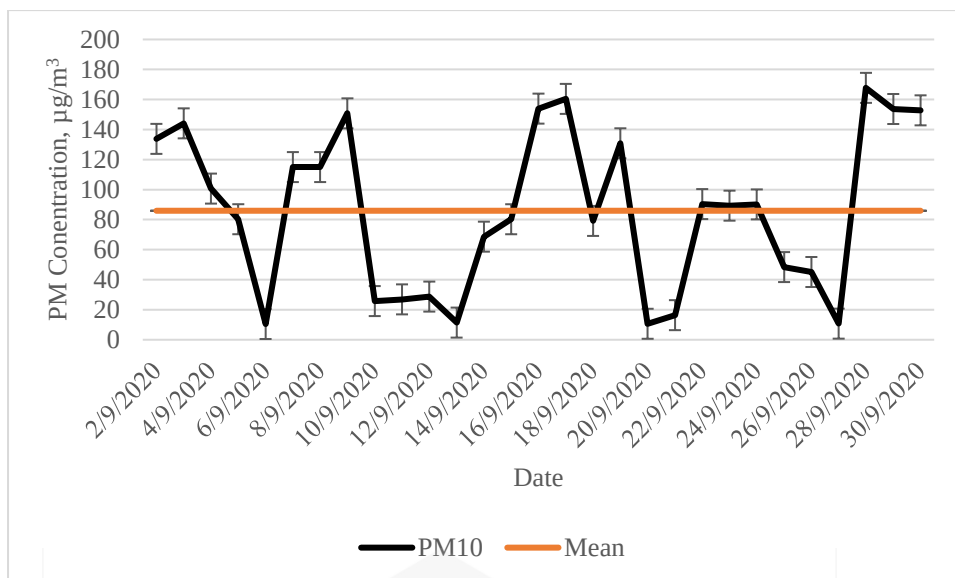


Figure 5.7 PM₁₀ Concentration vs Mean of September 2020.

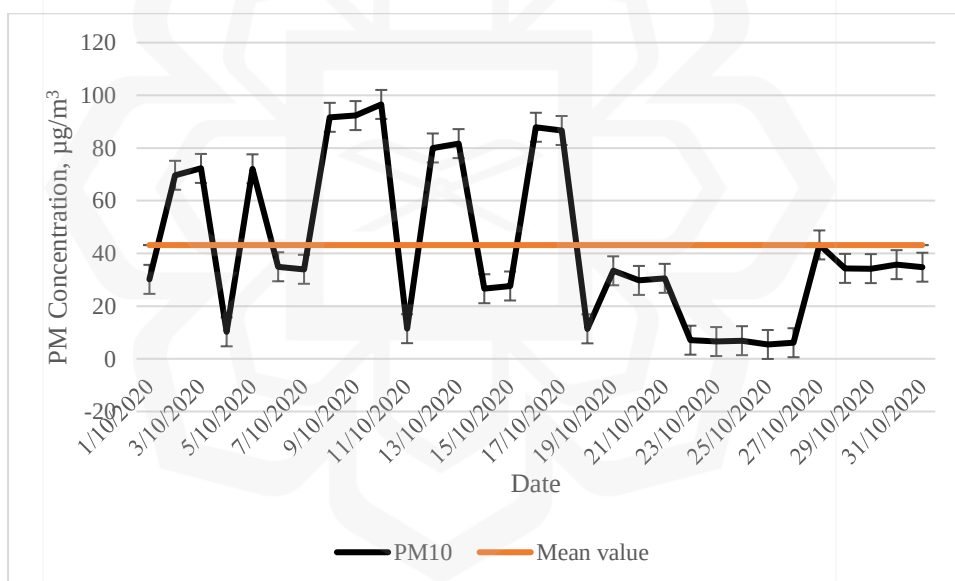


Figure 5.8 PM₁₀ Concentration vs Mean of October 2020

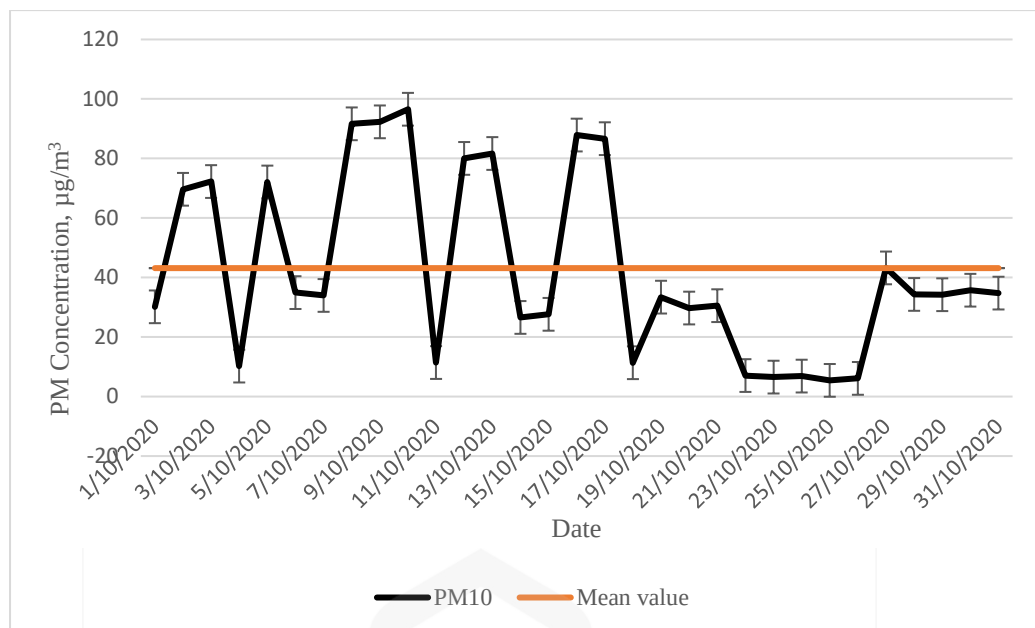


Figure 5.9 PM₁₀ Concentration vs Mean of August 2020

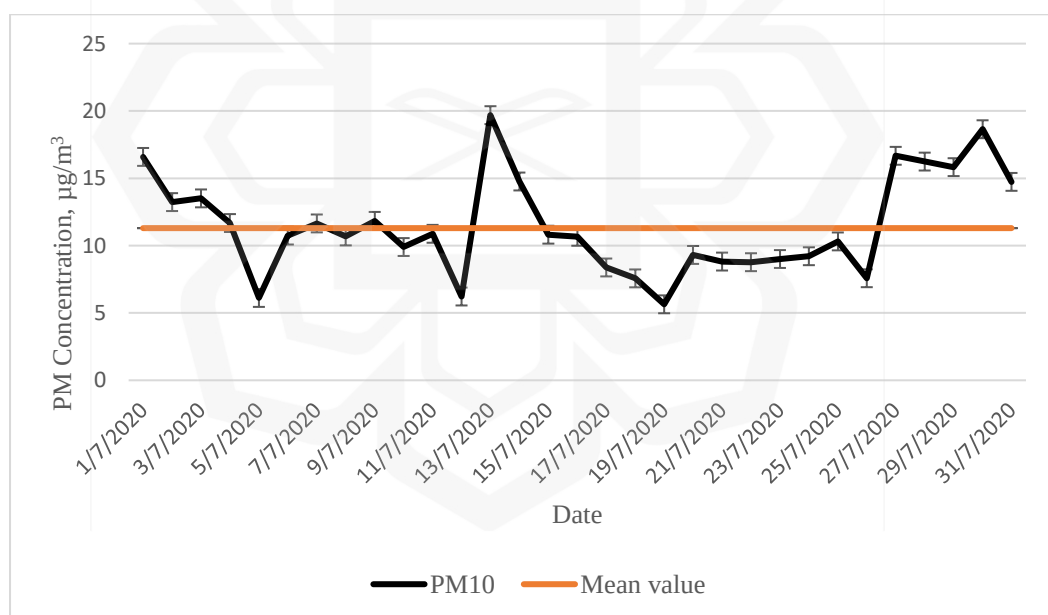


Figure 5.10 PM₁₀ Concentration vs Mean of July 2020

For PM₁₀, September stated the highest mean with 85.91 µg/m³ respectively followed by October with 43.16 µg/m³, the month of August with 41.99 µg/m³, July with 6.47 µg/m³ and June with 10.71 µg/m³. The lowest mean was in November with 6.36 µg/m³ respectively. Figure 5.7 shows 53.33% of PM₁₀ concentration above the mean value with error bars in September 2020 where a total of 16 days in September is

above the mean level. Figure 5.8 shows that 35.48% of PM_{10} concentration in October was above the mean value with error bars where a total of 11 days is above the mean level. Figure 5.9 shows that 2.26% of PM_{10} in August was above the mean value for 7 days. While in July and June, 38.71% and 33.33% are above the mean value that occurs within 12 and 10 days. However, in November about 43.33% is above the mean value for 13 days.

The conclusion from the mean above is that $PM_{2.5}$ and PM_{10} are released over 10 days every month during the construction site activities. The release of emissions is difficult to contain because the activities in the construction area must continue to achieve the construction target. The frequency of PM_{10} and $PM_{2.5}$ emissions occurs when many construction activities are carried out and the type of activity that occurs produces high PM_{10} and $PM_{2.5}$ emissions.

5.2.1.2 Median

Figure 5.11 shows that $PM_{2.5}$ in September has the highest median value with $18.03 \mu\text{g}/\text{m}^3$, followed by August with $10.32 \mu\text{g}/\text{m}^3$ and October with $8.53 \mu\text{g}/\text{m}^3$. June and July showed similar mean values with $6.10 \mu\text{g}/\text{m}^3$ and $6.13 \mu\text{g}/\text{m}^3$ respectively. At the same time, November shows the lowest mean value with $1.89 \mu\text{g}/\text{m}^3$. However, PM_{10} in September shows the highest with $89.30 \mu\text{g}/\text{m}^3$ followed by $34.27 \mu\text{g}/\text{m}^3$ in October respectively. In August the PM_{10} median was $21.75 \mu\text{g}/\text{m}^3$, while July and June stated $10.71 \mu\text{g}/\text{m}^3$ and $10.36 \mu\text{g}/\text{m}^3$. November stated the lowest median PM_{10} with $4.76 \mu\text{g}/\text{m}^3$. The median is a middle position when all the monitoring data is arranged in descending/ascending order from the smallest number to the highest number. The median helps to understand the average exposure level of the population to $PM_{2.5}$ and PM_{10} dispersion by mitigating the influence of extreme values in the dataset.

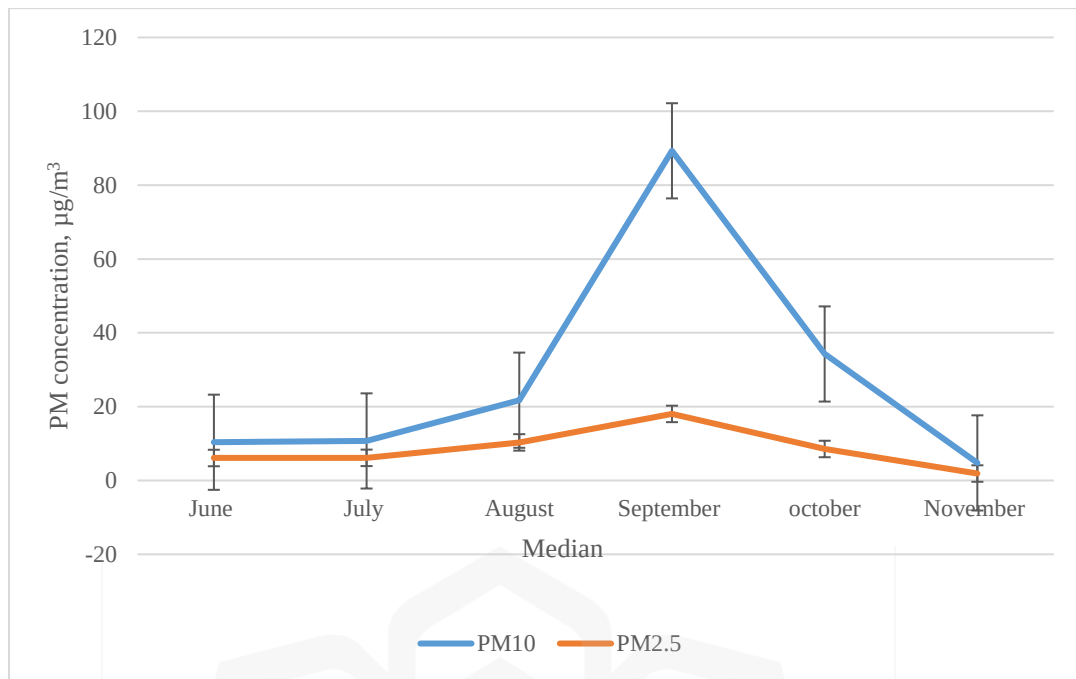


Figure 5.11 Comparison median of PM_{2.5} and PM₁₀ concentration

5.2.1.3 Minimum and Maximum Value

The minimum and maximum values showed the lowest and the highest emission of particulate matter. Every month showed different minimum and maximum values detected by the air quality equipment. Figure 5.12 shows PM_{2.5} where September scored the highest maximum value with 38.88 µg/m³ and November showed the lowest maximum value with 5.65 µg/m³. While October shows a minimum value of 2.76 µg/m³ and September shows the highest minimum value 5.83 µg/m³.

However, PM₁₀ shows slightly different results. September scored the highest maximum value with 167.77 µg/m³ and June showed the lowest maximum value with 16.64 µg/m³. For minimum value, November shows the lowest minimum value with 2.29 µg/m³ and September show the highest minimum value with 10.48 µg/m³. The minimum and maximum values indicate a high, heavy volume and identify the activity carried out at the construction site.

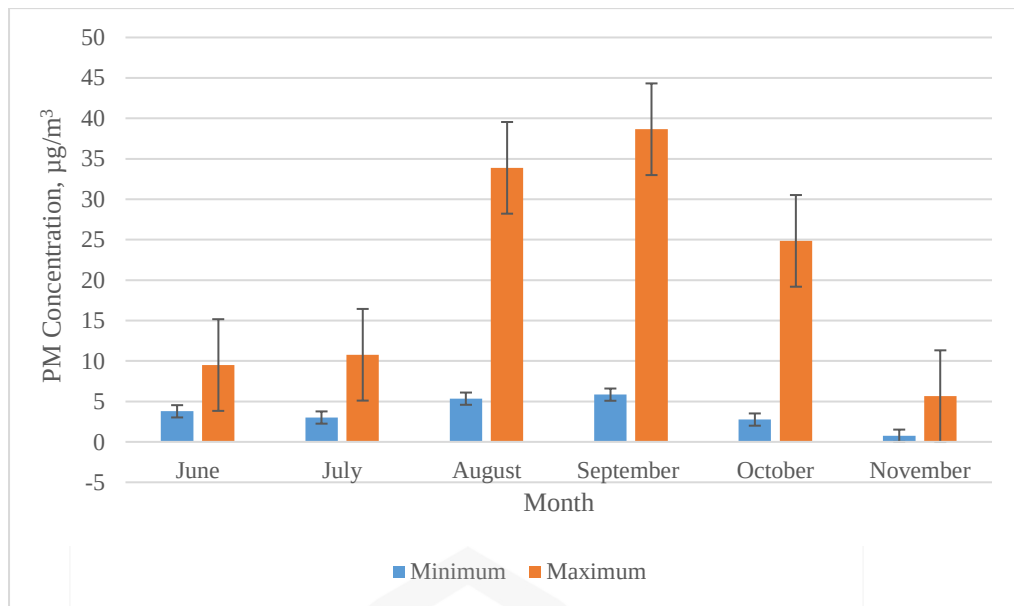


Figure 5.12 PM_{2.5} concentration in six-month monitoring. The Error bars represent the minimum and maximum values.

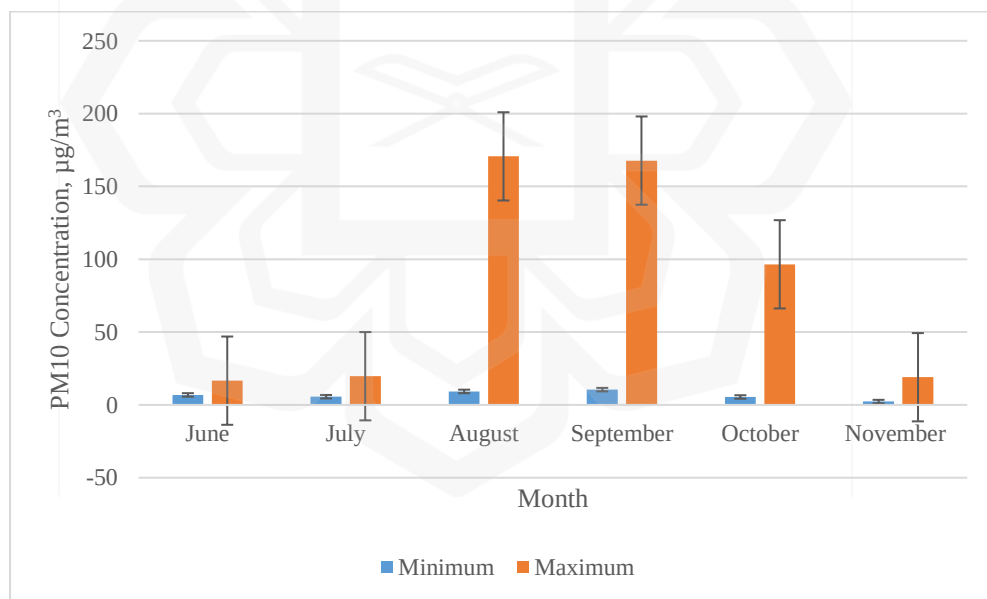


Figure 5.13 PM₁₀ concentration in six-month monitoring. The Error bars represent the minimum and maximum values.

5.2.1.4 Comparison $PM_{2.5}$ with Malaysia Ambient Air Quality Standard

Figure 5.14 and Figure 5.15 shows the pattern distribution that $PM_{2.5}$ and PM_{10} from June to September 2020 against the New Malaysia Ambient Air Quality Standard (MAAQS 2020). About 20% of the data set and 6 days in September are above the $35 \mu\text{g}/\text{m}^3$ 24-hr $PM_{2.5}$ MAAQS 2020. During the 6 months of monitoring, only 10% of $PM_{2.5}$ concentration exceeded the MAAQS 2020. Compared to PM_{10} , 2 months exceeded the air standard where 43% of the data set in September for 6 days and 16% of the data set in August for 5 days were above in the $100 \mu\text{g}/\text{m}^3$ 24-hr PM_{10} MAAQS 2020.

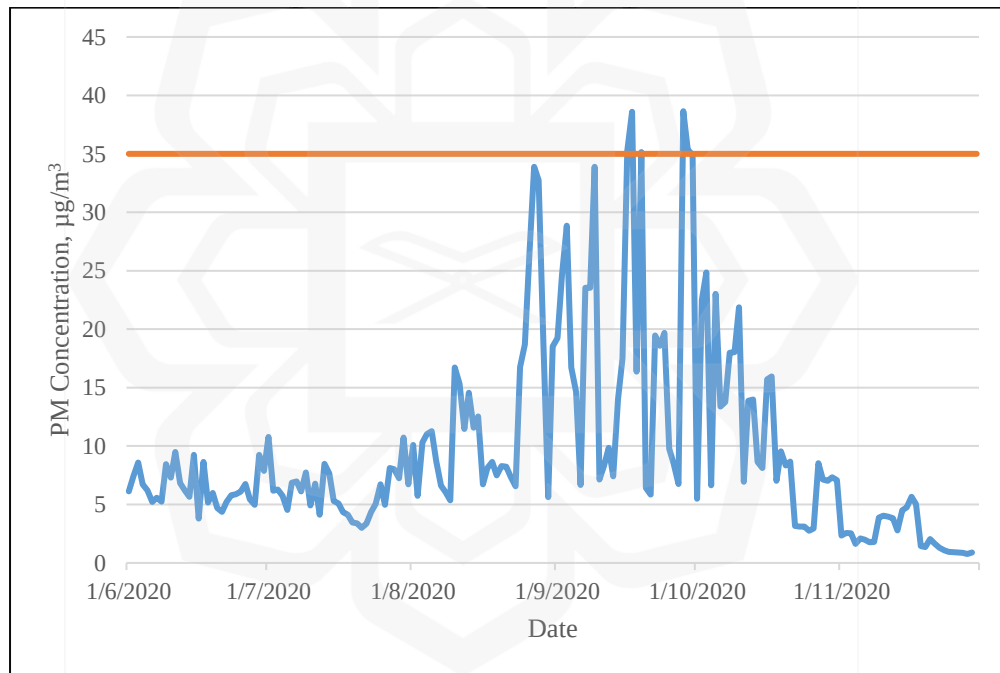


Figure 5.14 Comparison of $PM_{2.5}$ with MAAQS 2020.

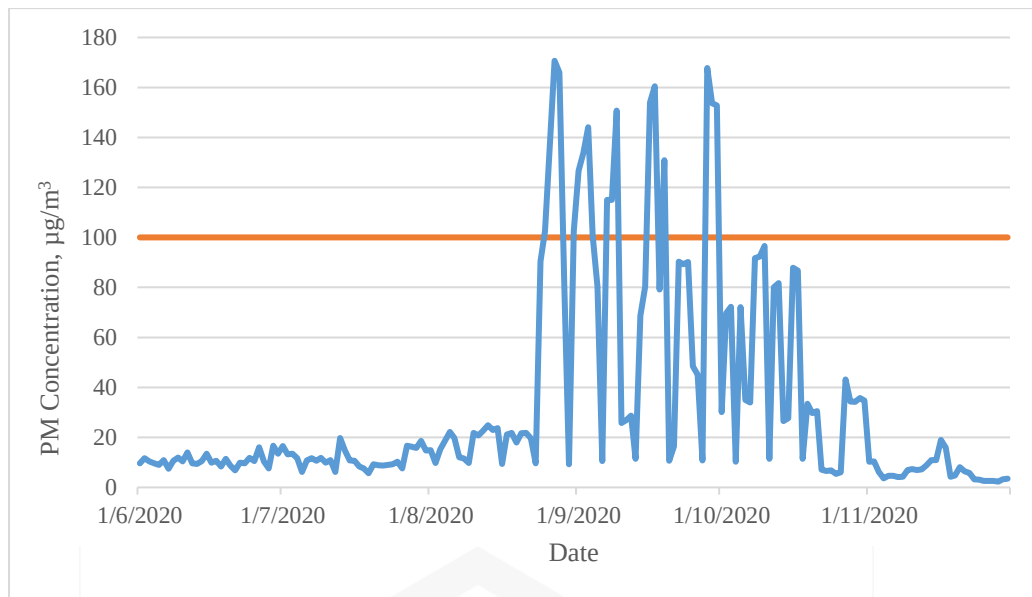


Figure 5.15 Comparison of PM₁₀ with MAAQS 2020

5.2.1.5 Analysis of Welch's T-Test on PM_{2.5} and PM₁₀

The findings from this study highlight the potential for consistency and alignment between in-situ monitoring data (monitoring site) and secondary data (DOE Monitoring Site) for air quality assessments in terms of particulate matter concentrations. The absence of statistically significant differences suggests that both monitoring methods provide comparable results, which may support the use of secondary data for broader environmental or epidemiological studies when in-situ data is unavailable or limited. The distance between monitoring site and the DOE monitoring site is 15 kilometer.

For PM₁₀ concentrations, the mean value recorded at the monitoring site was notably higher compared to the DOE Monitoring Site. This variation could be attributed to the localized nature of in-situ monitoring practices. In-situ monitoring sites often capture specific environmental conditions influenced by nearby pollutant sources, whereas secondary data from DOE Monitoring Sites may represent aggregated or averaged conditions over a broader area. This difference in monitoring methodologies may explain the larger standard deviation observed in the monitoring site data, reflecting localized fluctuations in air quality levels.

In terms of PM_{2.5} concentrations, the relatively smaller differences between the two datasets, as well as the lack of significant variation, suggest a higher degree of consistency in monitoring fine particulate matter. Unlike PM₁₀, PM_{2.5} particles are more uniform and widespread due to their smaller size and ability to travel long distances. This characteristic makes PM_{2.5} concentrations less influenced by localized environmental conditions, leading to more consistent measurements across different monitoring methods.

The results of this study have several implications for air quality monitoring and policy development. First, the findings suggest that secondary data from DOE Monitoring Sites can serve as a reliable source of information for PM₁₀ and PM_{2.5} levels, particularly in resource-constrained settings where in-situ monitoring is not feasible. Second, the slight variations observed between the datasets underscore the importance of calibration and methodological standardization across monitoring systems to ensure consistency and comparability in reported values. Lastly, as PM₁₀ and PM_{2.5} are critical indicators of air quality, ensuring the reliability of data from multiple sources can improve air quality monitoring frameworks and inform effective public health strategies.

This study, however, is limited by its relatively small sample size of six months and the lack of spatial information regarding the exact locations of the monitoring sites. Future studies should consider using larger datasets that cover more locations and extended time periods to better assess broader trends in particulate matter levels. Additionally, further research should examine the correlation and agreement between in-situ and secondary data sources across various regions and seasons. Exploring how differences in monitoring methodologies influence measurements could also provide valuable insights into improving air quality assessment protocols.

5.2.2 RO2: Sources/Activities of Significant Components of PM Emanating from a Construction Site.

The collection of air quality monitoring was started in May 2019 at Prima Construction at Gambang, Kuantan. The monitoring was in the schedule as planned in my progress planning the air quality monitoring was expected to be running for one year of monitoring. In the early month of monitoring, it was very smooth but in October 2019, the developer had to stop temporary work due to stop funding by the federal government. In March 2020, the study area was shifted to a new monitoring site at Priya Construction, and PM_{2.5} and PM₁₀ were monitored for 6 months.

The construction site must temporarily close for 3 months from March to May 2020 to obey the MCO. Malaysia was hit by the Coronavirus pandemic back in December 2019. The pandemic started to grow in our country, and in March 2020 the Malaysian Government had to implement a Malaysia Control Order (MCO) nationwide, under the Prevention and Control of Infectious Diseases Act to control movement and prevent the spread of COVID-19. During this period, all operation and activities construction sector is closed under the MCO to comply with the relevant MCO Standard operating procedure (SOP).

However, in June and July 2020, the construction site was allowed to work but the IBS (Industrialized Building System) building materials such as cement, concrete, sand, soil, slabs, steel beam, columns, portal frames, and root trusses were slow in progress and its take times to arrive. The building material was transferred from Selangor and other states where '*Surat Kebenaran Merentas Negeri*' and other support letters need to be prepared before the transportation starts. Therefore, less work and less movement are transported to the construction site. Figure 5.1 9 shows the condition of the construction site on 12th June 2020 where the only concrete foundation was done at the site. Other construction activities were slow but still in progress.

The presence of COVID-19 has slowed down this study and even shortened the time from a year to 6 months. In addition to that, travel restrictions by the government have prevented the movement during the period of this study and caused various documents such as travel documents, letters of support and other documents to be

prepared to continue this study at the construction site. There are various government directives that the developer must comply with such as Emergency Ordinance (Prevention and Control of Infectious Diseases) (Amendment) 2021, Act 342 (Prevention and Control of Infectious Diseases Act 1988), subject to the rules in the MKN general SOP regarding MCO, PKPB and PKPP and subject to local authority regulations in force.

Figure. 5.16 shows the foundation was already built in December 2019 but due to financial problems, workers and management issues, the progress of construction had been stopped and delayed until it continued in March 2020. However, financial costs become a problem in COVID-19 where the cost of materials increases and the absence of general construction workers who have been sent home by the government. Thus, construction activity slows down and PM emissions decrease with the absence of active activity in the construction area

In July 2020, the graph slightly fluctuated throughout the month. The range of the graph is slightly higher than the previous month (June) with a minimum value of $3.01 \mu\text{g}/\text{m}^3$ and a maximum value is $10.77 \mu\text{g}/\text{m}^3$. The range of $\text{PM}_{2.5}$ and PM_{10} concentrations in June was still below the Malaysia Ambient Air Quality Standard 2020. Figure 5.19 shows the construction slowly operates at the site and the activities involved such as digging a hole and pouring concrete to form a foundation, and base, earth excavation and levelling soil, placement of reinforcement steel, erection of concrete formworks for footings, placement of concrete and vibrating and levelling of concrete surface and removal of formwork.



Figure 5.16 Foundation condition at the construction site on 12th June 2020.

However, the activities continued actively and started to rock vigorously in August, September, and October 2020 due to the government has allowed the construction sector to operate fully. Transporters such as tipper trucks carried soil and sand, cement mixer trucks, and trailer trucks moved heavily in and out of the construction site. Other than that, the movement of excavators and dump trucks also contributes to the $PM_{2.5}$ and PM_{10} emissions.

The developer has acted by setting up safety signage such as reducing the speed limit to not more than 15 km/h and laying crusher run on-site. However, the attitude and behaviour of the drivers themselves cannot be controlled. Some lorry and truck drivers disobey the rules and drive more than the speed limits stated at the construction site. This can be seen during observation in the study area where lorries violate the speed limit in the construction area

Figure 5.18 shows the crusher run was placed at the entrance and near the site office the site act as a temporary road at the construction site to reduce dust and emission of particulate matter. However, on a certain road at the construction site, the crusher run was not in place. The developer left the road in bare soil and was exposed to rain and wind. When the dump truck ran over the crusher run, a huge volume of dust was admitted into the atmosphere and polluted the air. This is not good practice that should be done at the site. The construction site became dusty and messy. The unpaved road at

the construction site should be placed on the crusher run to reduce the impact of emissions and to reduce mud formation during heavy rain. The mud formation can cause the road to become slippery for heavy vehicles and might cause an accident on rainy days. The maintenance of the crusher run was done at the site but due to the recurrent movement of heavy vehicles and machinery. The designated crusher runs damaged and fails from time to time and becomes worse during the rainy season.

Figure 5.17 shows the speed signage is also only placed at the entrance. There is no sequence speed signage available inside the construction site. Many lorries and dump trucks slow at the entrance but start to push the feet paddle and go speed more than 15 km/h inside the construction site. Many truck and lorry drivers disobey the speed limit rules. The lorry driver prefers driving fast rather than thinking about their safety. However, it can be the driver intentionally or it could be unintentionally driving fast. The developer has done their part in defining the speed limit inside the construction site only human characteristics choose to follow or obey the rules.

At the construction site, there is no air quality monitoring equipment placed by the developer. The dust or particulate emission at the site was not monitored by the developer as it was not in their bill of quantities (BoQ or BQ) listing as an item. The emission of dust or particulate matter was not taken seriously by the developer to monitor and control the emission. During the planning stage, dust or particulate matter are just normal issues and do not fall on critical or major issues during early planning of project design by top management. The issues are normal and don't cause health or environmental impact to the environment.



Figure 5.17 Signage speed limits at the construction site.

The average temperature at the construction site from June to November 2020 is within the range of 24.1°C to 29.8°C (75 °F-84°F) respectively. The lowest temperature was in November 2020 and the highest temperature was in August 2020. Overall, the temperature is normal and stable throughout the year. In Malaysia, we are not experiencing extreme temperatures such as extreme heat temperatures in countries like Burkina Faso, Botswana, Algeria, Chad, Ghana, Nigeria, and Niger and extremely cold temperatures in the country such as Norway, Lesotho, New Zealand, and Russia. Therefore, due to our tropical rainforest climate, we are lucky that our business, construction, and other jobs can work throughout the year without experiencing high and cold extreme weather. Nevertheless, we will experience the wet season in the east between November and February and the dry season between April to October.



Figure 5.18 Crusher run acts as a temporary road at the construction site.

The humidity for six-month monitoring showed that the minimum relative humidity was 75.1% and the maximum relative humidity was 93.2%. Relative humidity means the amount of moisture or water vapor in the air. June, July, and November 2020 showed the month that has high humidity in the atmosphere. However, November showed the highest humidity with a minimum value, of 81% and a maximum value, of 93.2%.

It is important to understand the duration period of rainfall. A high amount of rainfall may cause flash floods, but a low amount of rainfall may cause drought in a vulnerable place. The mean average rainfall is 7 mm for the six-month monitoring period. In Jun and July, the rainfall is quite high compared to August, September, and October. However, the amount of rainfall is not as high during the northeast monsoon. Between late May to September, the east coast will experience a southwest Monsoon which has less rainfall and lots of sun. This is the best time to clear land or increase or add on activity construction to achieve progress. Therefore during these months, the activities at a the construction site are slow but still in progress due to rainy days.



Figure 5.19 Concreting and cementing in progress during dry weather.

5.2.3 RO3: Analysis of Data Collection using Meteorological Software and Environmental Modelling.

From the WRPLOT analysis as discussed in Chapter 4, the prevailing wind at the construction site is a wind that blows predominantly from the South (S) 15% of the time, other wind blows from South-Southwest (SSW) about 9.2% of the time, North (N) with 8.6% of the time and from North-Northwest (NNW) with 7.7% of the time and other wind that less than 5% at any direction of the time. The wind carried the particulate matter as the wind passed through the construction site. Figure 5.24 shows the wind rose pattern within a six month of monitoring period blowing from the South and any direction across the research site within a 5 km radius as mapped in Google Earth. Figure 5.21 shows the wind rose blowing in the other direction across the research site towards to north area.

Within the 5 km radius, there are Rumah Kanak-Kanak Sultanah Hajjah Kalsom (RKKSHK), Penor Prison Complex, Asnaf Complex, school, and several residential areas located near the research area (discussed in detail in chapter 3). Another land use area is vegetation such as palm oil plantations. Figures 5.22 and 5.23 show the radius

in kilometers where the construction site is the center point of the radius. The red circle line is a 1 km radius, followed by the green circle is a 2 km radius, the yellow circle is a 3 km radius, the purple circle is a 4 km radius, and the light blue is a 5 km radius from the construction site respectively. The radius was used to measure the dispersion distance (km) of $PM_{2.5}$ from the construction site and to see any potential reach to sensitive receptors in the surrounding area.

The wind blowing from the south predominately to the north area where RKKSHK and Penor Prison Complex are located. Figure 5.20 shows that the Rumah Kanak-Kanak Sultan Hajah Kalsom (RKKSHK) is just adjacent to the research site. There is no buffer zone existing between the research area and RKKSHK but only a fence separating both areas. There are several trees at the boundary but the RKKSHK is highly exposed to dispersion of $PM_{2.5}$.



Figure 5.20 Borderline between RKKSHK and the construction site.

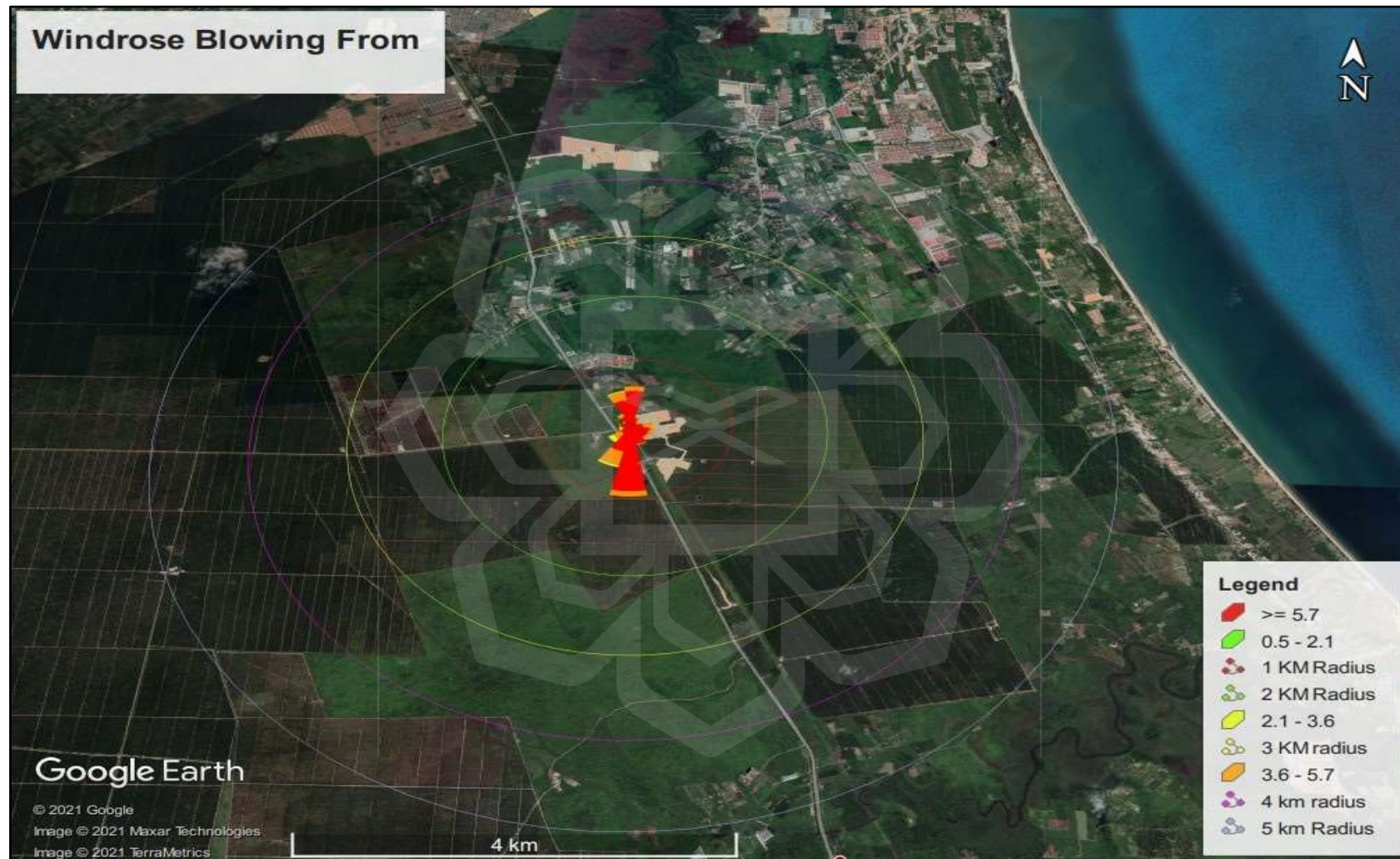


Figure 5.21 Windrose pattern blowing from at the research site within a 5 km radius. Zooming in 3 km.



Figure 5.22 Windrose pattern blowing to research site within a 5 km radius. Zooming in 3 km.

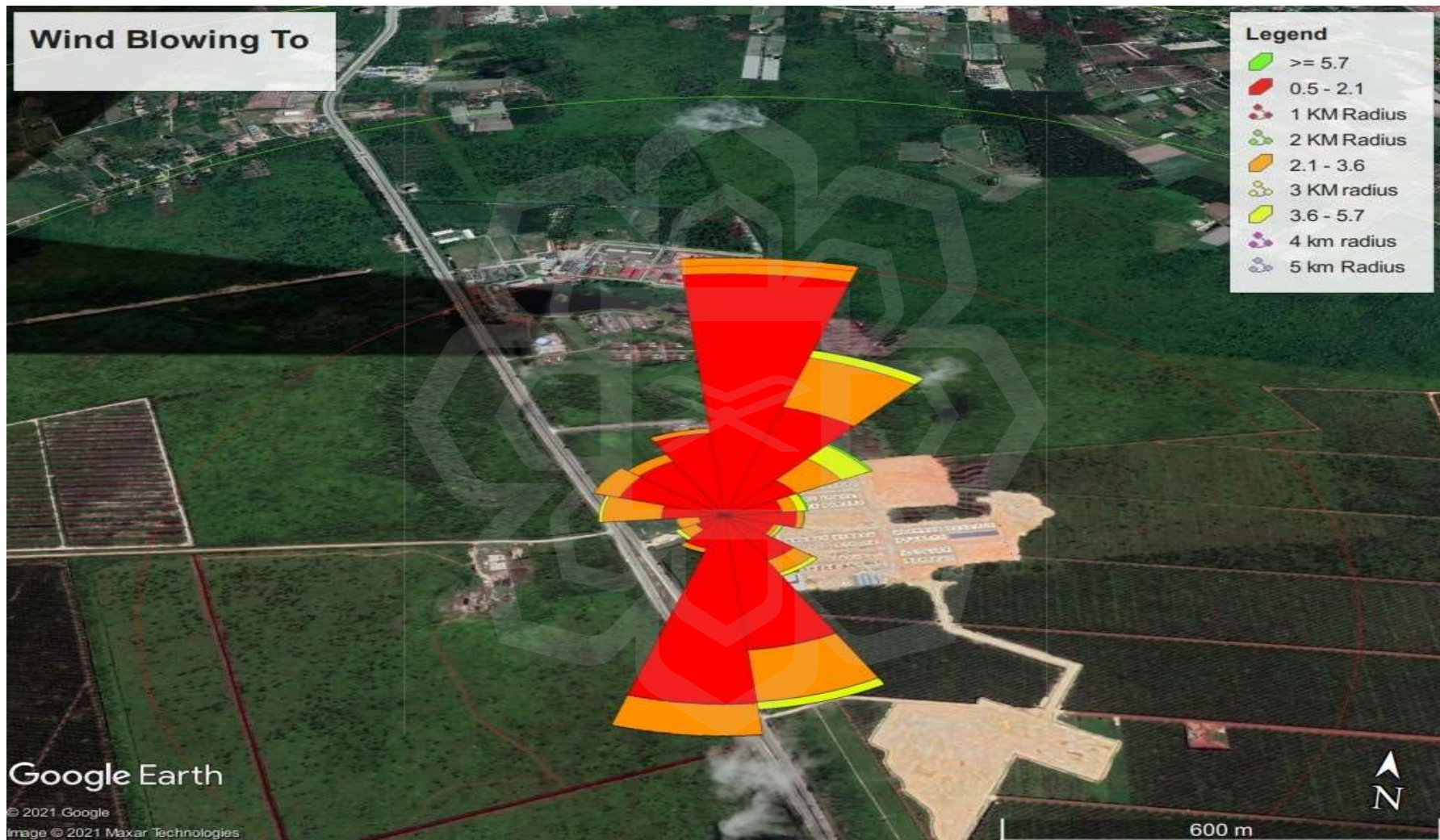


Figure 5.23 Wind rose (blowing to) in short distance of 600 meters zooming

The RKKSHK is the close recipient to have an impact on particulate matter distribution from the research site. Figure 5.23 shows the wind rose ‘blowing to’ towards the north part and in several directions in a short distance of 600 meters zooming using Google Earth. The Penor Prison Complex also had the same impact as the wind pushed the airborne particulate matter in the north direction where the Penor Prison Complex is in the north part and adjacent to the RKKSHK. The presence of this wind plays an important role in spreading PM_{2.5} in the surrounding study area.

Figure 5.24 shows the calendar plot of PM_{2.5} concentration from June until November 2020. A calendar plot is very useful in representing data in a visual presentation on the time scale of months and days in the form of a calendar format. The identification of anomalies, trends, and patterns through calendar plots helps in understanding the frequency and distribution of meteorological data across different years, months, and dates. The daily PM_{2.5} concentrations are calculated by using the `timeAverage()` in `openair` by default consuming the daily PM_{2.5} data monitoring.

The calendar plot defines the PM_{2.5} concentration from 0 µg/m³ and above 35 µg/m³. The indicator of PM_{2.5} concentration is at the side of the calendar plot. The PM_{2.5} concentration is plotted in numbers, replacing the number of days. The PM_{2.5} concentration is also determined by different colour distributions. Figure 5.27 shows in June, July, and November, the PM_{2.5} concentration is less than 10 µg/m³ with shows brown and light brown colour. Whereas, in August, September, and October 2020, the PM_{2.5} concentration exceeded 10 µg/m³ that shown in orange, dark orange, light red, red, and dark red colour.

The calendar shows that in August, September, and October the emission of PM_{2.5} at the construction site is slightly high. During these months, many construction activities were involved, and many movements of workers and vehicles occurred inside the site. The clearing and filling activities also occurred on the other plot at the construction site, therefore much soil and sand were brought from outsourcing into the construction site. Other than that, the lack of vegetation causes a large amount of dust emission to pollute the surroundings. The behavioral problem and lack of awareness of the environmental aspect, contribute to the PM_{2.5} emission factor. The project proponent and contractor need to speed up the construction activities due to delaying the project

schedule because of MCO and RMCO. Therefore, the activities at construction all occurred at one time without following the phase period. During MCO, construction is not prohibited to be carried out at the site.

In June and July, the workers at the construction site were still working as usual but due to MCO many activities were stranded and slowed down. The activities such as The $PM_{2.5}$ concentration can be seen in the calendar plot where in June and July the concentration is less than $10 \mu g/m^3$, except in July on 1st July and 30th July where the $PM_{2.5}$ concentration is $11 \mu g/m^3$. The construction activities only occur during the daytime and the working hours are from 8.00 am till 6.00 pm.

For the distribution of PM_{10} cannot be done because the openair software disappeared during the formatting of this computer. Therefore, only the spread of $PM_{2.5}$ can be explained and discussed in this study.

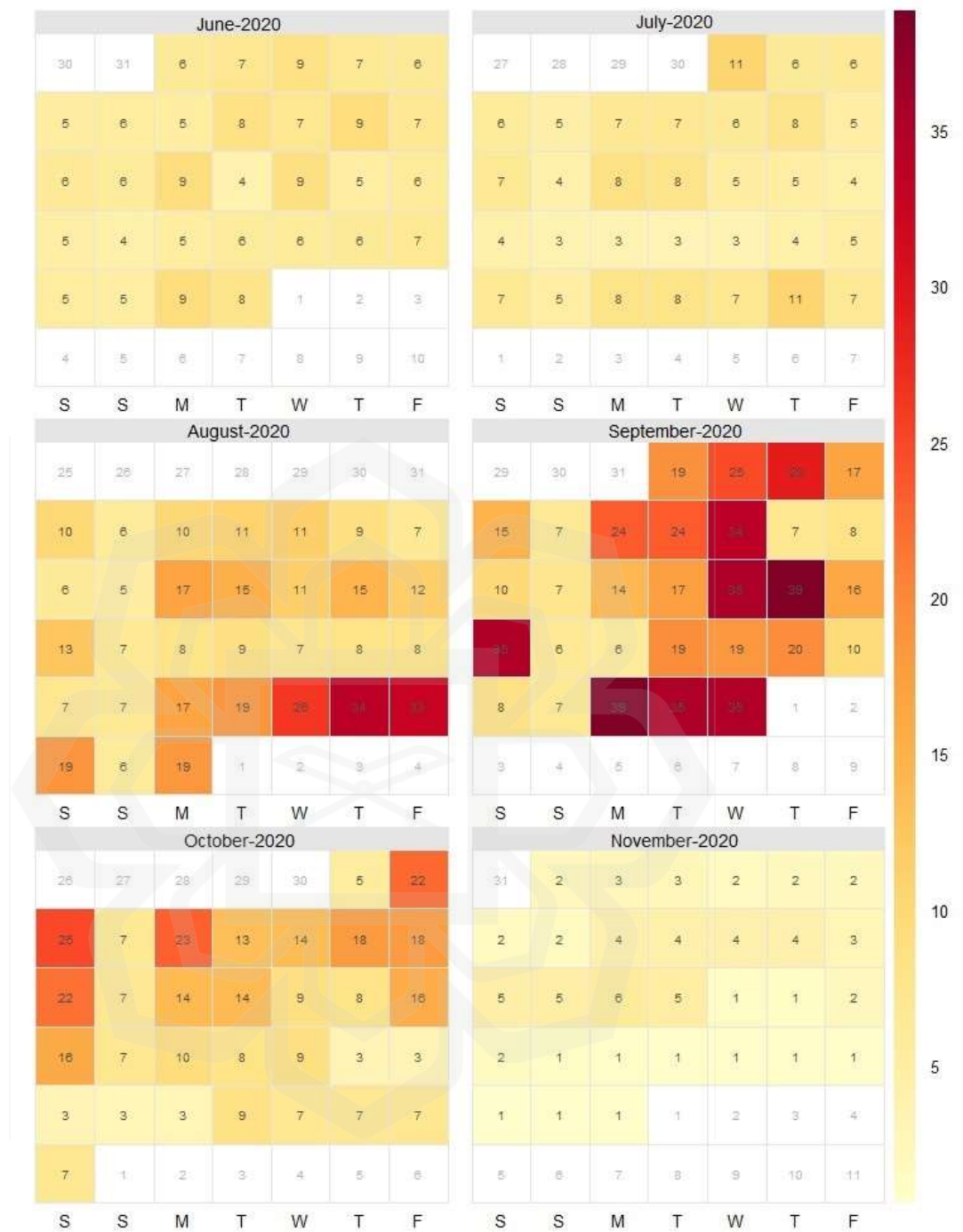


Figure 5.24 Calendar Plot PM_{2.5} concentration from June to November 2020. (R Studio, Version 1,4,1103,0)

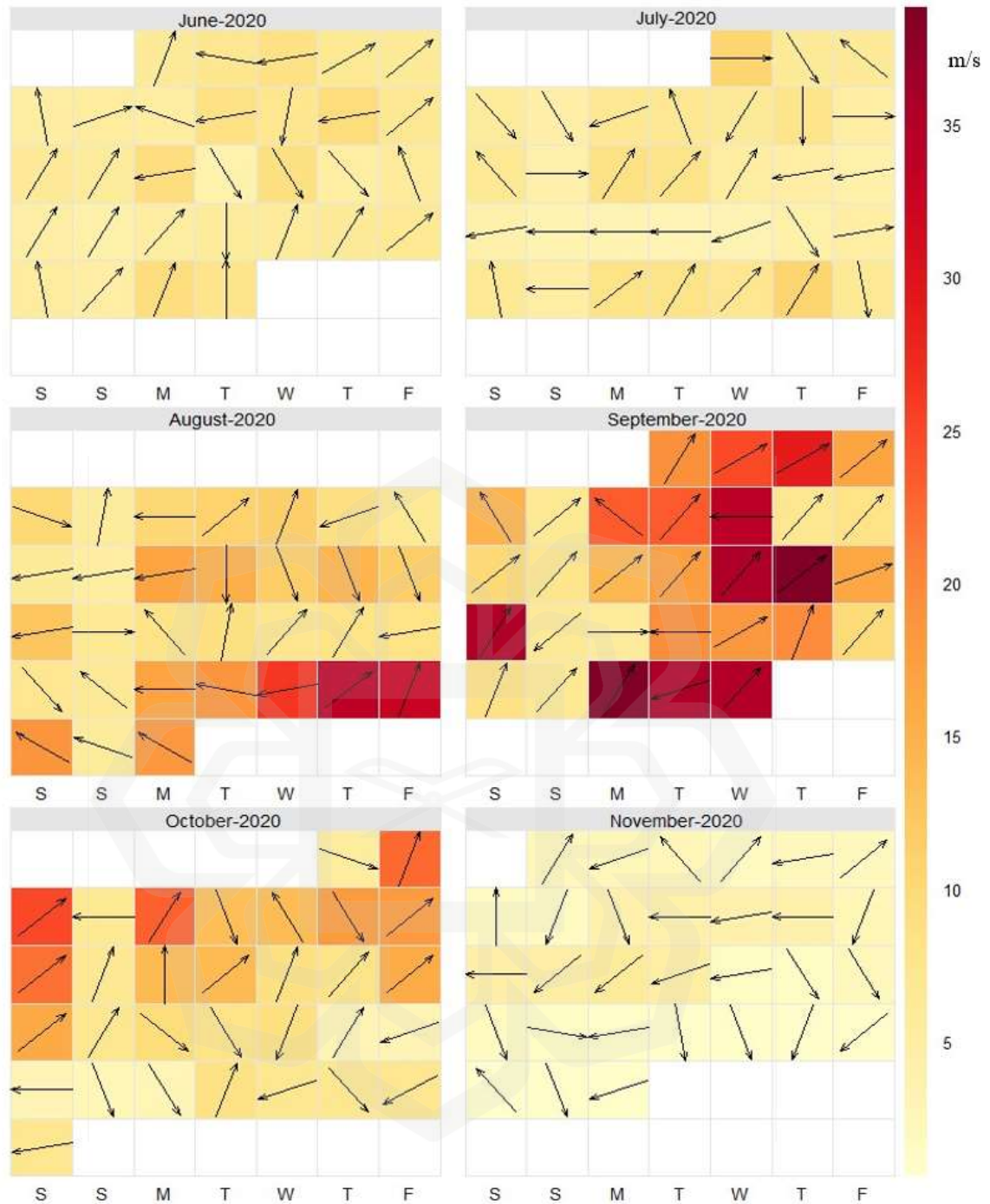


Figure 5.25 Calendar Plot showing the wind direction and wind speed by day from June to November 2020 using Rstudio.. The darker colours indicate higher winds, and the arrow shows the prevailing wind direction for that day.

In November, the $PM_{2.5}$ concentration is below $10 \mu g/m^3$ respectively from the construction site. In this month the $PM_{2.5}$ concentration is the lowest concentration

number produced compared to other five-month monitoring. This is due to of northeast monsoon that brings heavy rainfall to areas on the east side of Peninsular Malaysia such as Kuantan and Borneo (Sabah and Sarawak). The average rainfall and humidity show the highest result compared to another month with 14.3 mm and 86.5%. The temperature is 26.3°C, the lowest temperature compared to another month. The heavy rainfall causes the activities at the research site such as clearing, filling, and excavation to stop operation.

Figure 5.25 shows the south wind and south-southwest wind prevailed across the construction site during August, September, and October 2020, thus the prevailing wind was favorable for PM_{2.5} dispersion. From June to September 2020, most of the prevailing winds blow from the south and south-southwest and blow to the north and north-northeast carrying the PM_{2.5}. The PM_{2.5} concentration is carried by the wind less than 10 µg/m³.

Table 5.1 shows the table of the Beaufort scale. The Beaufort scale or known as the Beauford wind force scale is an empirical measurement that is used to observe the condition at land and sea related to wind speed. The Beauford scale was developed by Francis Beauford an Irish hydrographer of a Royal Navy officer in 1805. The Beauford chart applied to land conditions with the description of wind speed. Therefore, the Beauford scale can be used as a refer scale for wind level.

5.2.4 RO4: Mapping the PM Pattern Dispersion on Environmental Modelling

Figure 5.26 shows the bivariate polar plot PM_{2.5} concentration relation by wind speed and wind direction at the construction site from June to November 2020. The scale colour shown as a PM_{2.5} concentration distribution reference. The scale represents five different colours of PM_{2.5} concentration distribution. The 'blue' represent concentration from 0 to 8 µg/m³, the 'light blue' represents concentration from 8 to 9 µg/m³, the 'light green' represents concentration from 9 to 10 µg/m³, the 'yellow' represent concentration from 10 to 11 µg/m³, the 'orange' represent concentration from 11 to 12 µg/m³, the 'red' represent concentration from 12 to 13 µg/m³ and the 'dark red' represent concentration from 13 µg/m³ and above.

Table 5.1 Beauford scale was used to measure wind speed that was applied both on the sea and on land. Note: The Beauford scale has 12 classes depending on wind speed and wave height.

Beaufort scale	Description	Wind Speed	Land condition
0	calm	<1 km/h	Smoke rises vertically
1	Light air	1-5 km/h	Direction is shown by smoke drift but not by wind vanes.
2	Light breeze	6-11 km/h	The wind felt on face, leaves rustle, wind vane moved by wind
3	Gentle breeze	12-19 km/h	Leaves and small twigs in constant motion, light flags extended.
4	Moderate breeze	20-28 km/h	Raises dust and loose paper, small branches moved.
5	Fresh breeze	29-38 km/h	Small trees in leaf begin to sway
6	Strong breeze	39-49 km/h	Large branches in motion; whistling heard in telegraph wires;
7	High wind, moderate gale, near gale	50-61 km/h	Whole trees in motion; inconvenience felt when walking against the wind
8	Gale, fresh gale	62-74 km/h	Twigs break off trees; which generally impedes progress
9	Strong/severe gale	75-88 km/h	Slight structural damage (chimney pots and slates removed)
10	Storm whole gale	89-102 km/h	Trees uprooted

The 'blue' shows the largest portion dispersion in the bivariate polar plot. It seems that the 'blue' was heading to the north where RKKSHK and Penor Prison Complex were located. The wind speeds between 4 m/s to 18 m/s blow (14.4 km/h to 64.8 km/h) from the south and south-southwest directions blow the lower PM_{2.5} concentration pollution, less than 8 µg/m³ (blue) to the north, northwest, southwest and northeast direction were located the RKKSHK and the Penor Prison Complex at north site. Refer to Figure 5.29 the Beauford scale is between 3 to 8 where Beauford number 3 is referred to a gentle breeze and Beauford number 8 refers to a fresh gale. Beauford number 3 is mentioned as leaves and small twigs in constant motion, moved by the wind while Beauford number 8 is mentioned as twigs breaking off trees, generally impeding progress.

The 'red' shows the wind speed between 8 m/s to 18 m/s (28.8 km/h to 64.8 km/h) blowing from north and north-northwest blowing with a higher concentration of PM_{2.5} more than 12 µg/m³ to the south-southwest, south-southeast, southwest (the largest portion) and southeast (lowest portion). Refer to table 5.1 the Beauford scale is between 4 to 8 where the Beauford number 4 is referred to as moderate breeze and Beauford number 8 is referred to as Gale, fresh gale. Beauford number 4 is mentioned as raising dust and loss of paper; small branches moved while Beauford number 8 is the same as above.

The 'light blue' wind speed between 2.1 m/s to 4.3 m/s (7.6 km/h to 15.5 km/h) blows from east, west, and north-northwest to west, east, and south-southeast with 8 µg/m³ to 9 µg/m³. The Beauford scale is between 4 to 5 where the Beauford number 4 is referred to as moderate breeze and Beauford number 5 is referred to as fresh breeze. Beauford number 4 is mentioned as raising dust and loose paper, the small branches moved while Beauford number 5 is mentioned as small trees in leaf begin to sway.

The 'yellow orange' wind speed between 1.43 m/s and 7.718 m/s (5.148 km/h to 27.79 km/h) blows from west, northwest, and northeast to southwest, southeast and east with 10 µg/m³ to 11 µg/m³. The Beauford scale is between 1 to 4 where Beauford number 1 is referred to as light air and Beauford number 4 is referred to as moderate breeze. Beauford number 1 is mentioned as the direction shown by smoke drift but not by wind vane while Beauford number 4 is mentioned as raises dust and loose paper, small branches moved.

The wind has the power to disperse the PM_{2.5} from one location to other. It is quite difficult to control the wind speed and wind direction as it is natural, we can control the sources of pollution where it comes. By controlling the sources of emission, the impact will be different where the concentration of PM_{2.5} will be reduced.

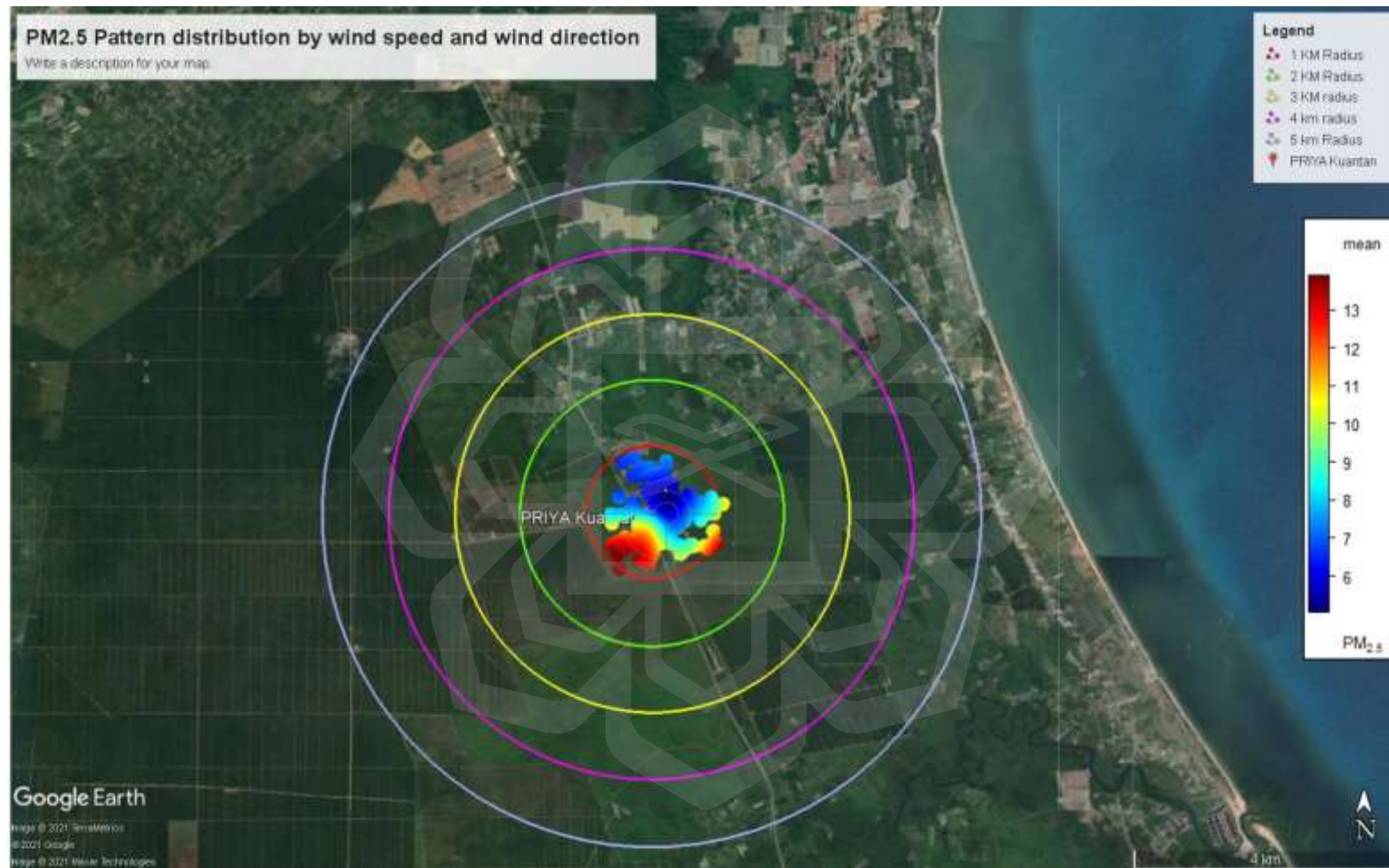


Figure 5.26 PM_{2.5} pattern distribution by wind speed and wind direction at the research site from June to November 2020.

5.2.5 RO5: Solutions from the Research Investigation Done

The implementation of this study proves that PM_{10} and $PM_{2.5}$ are the most air pollutants released in construction areas before and during construction. The impact of this particulate emission causes the surrounding area to be affected and impacts their health. In Malaysia, we have a government agency that monitors air quality, and we also have an agency that grants construction licenses to regulate the construction industry by ensuring that the companies involved meet certain technical and financial standards. But are these agencies able to control air quality emissions from the construction area continuously before the construction starts and is ongoing? These agencies should be ready to open a space for cooperation and regulate air emissions so that they comply with the standards set by Malaysia.

5.2.5.1 *Impact of PM Dispersion on Communities.*

From this study, air pollution from the study area impacts the environment and health of the surrounding area. This can be seen in descriptive analysis, which shows that $PM_{2.5}$ and PM_{10} emissions are very high in August, September, and October. With the presence of velocity and wind direction blowing towards the north, it spread the $PM_{2.5}$ and PM_{10} towards Rumah Kanak-Kanak Sultanah Hajjah Kalsom and Penor Prison. Rumah kanak-kanak Sultanah Hajjah Kalsom is the worst receptor receiving dust impact release from the study area. The receptor's house is located only 5 meters from the boundary of the study construction area, very close and there are no trees or buffers presence there. This condition caused dust to disperse and settle onto the walls and windows of the receptor house. Penor prison area also gets the impact of air pollution from the study area. where the officers' vehicles and clothes were found to be dusty and dirty throughout the construction.

The developer does not provide any compensation to the receiver of the impact. The developer has opened the construction phase on a large scale and more activities such as cutting down trees, clearing land, and moving trucks in the study area contribute to the release of $PM_{2.5}$ and PM_{10} . CIBD and local authority (MBK) do not monitor activities and air quality emission occurring in the study area. This causes developers

to fearlessly not follow the regular schedule and planning as planned. The situation getting worse when it occurs in the month of September where the season is dry and hot, which causes a lot of dust ($PM_{2.5}$ and PM_{10}) to be emitted into the air. The presence of this dust also interferes with the visibility of Kuantan-Pekan road users where the road and intersection areas are dusty.

The solution is to adhering to the planning schedule is something that can help in overcoming the emissions from the source and also it can reduce the impact on the environment. increasing speed and warning boards in construction areas and warning drivers who do not comply with the speed set by the developer. This matter will be explained in more detail in the recommendations in Chapter 6.

5.2.5.2 *Lack of Documents, Laws, and Guidelines.*

Malaysian Construction Industry Development Board (CIDB) is an expert agency in the local construction industry that carries out functions related to construction under the Construction Industry Development Board Act 1994 (ACT 520). CIDB did not take any action on air quality matters. Refer to the guidelines in the CIDB CIS 17:2010 (Guidelines for working at noisy and dusty areas in construction sites) and explain that the total air sampling time must be at least 7 hours and not monitored for 24 hours. The CIDB guideline itself does not comply with Malaysia Ambient Air Quality Standard (MAAQS) which is applied currently where the air emission needs to be monitored for 24 hours. CIDB should amend the content of these guidelines to comply with MAAQS standards and restrict the release of $PM_{2.5}$ and PM_{10} from the construction area.

Act 520 is an act provided to form CIBD in 1994. Under this act offers CIBD expertise in the local construction industry and other matters related to construction. This Act does not touch any matter involving the preservation and conservation of the environment. Therefore, imposing a compound or fine on the developer cannot be done because no section or regulation is subject in this act on polluting the environment. CIDB also does not have provisions for fines for offences committed by developers who violate these guidelines on air quality emissions.

The Kuantan City Council (MBK) has Acts and laws that are used to govern the residents of Kuantan District. However, none of these Acts and by-laws have been implemented compulsory in implementing the continuous monitoring of PM_{2.5} and PM₁₀ in construction areas. The absence of laws in the monitoring of PM_{2.5} and PM₁₀ will cause continuous emissions from the construction area and no action can be taken by the MBK against violation of the developer. Residents in the Kuantan district can only complain about the dust (particulate matter) but the action of summons or compound against the developer cannot be done because it is not in the provisions of the bylaws. It is a serious matter as it is one of the important elements in contributing to the development of the city of Kuantan towards a sustainable and livable city.

The 2022 Edition Local Plan Manual prepared by the Town and Country Planning Department (PLANMalaysia) in December 2022, is a document that is used as a guideline in the preparation of an effective and comprehensive local plan document for regional development. This document touches a lot on the planning process such as the planning period, the appointment of consultants, the preparation of geospatial land use, analysis reports and development strategies and public participation and publicity. Under the item environmental quality and natural resource management, the air quality management is stated in this document. However, the parameters PM_{2.5} and PM₁₀ are not specified in this document and there is no continuous monitoring of these parameters to be planned in the regional document at the construction site. On the other hand, total suspended particulate (TSP) is the parameter specified and to be monitored is contained in this document. The absence of continuous monitoring of PM_{2.5} and PM₁₀ in this document does not reflect how important it is to tackle the emission of parameters that will have an impact on the residents and surrounding areas. planned development planning may cause the implementation of the development to be stopped either immediately or in phases.

The Department of Environment (DOE) is Malaysia's government agency responsible for environmental management. The Department's enforcement actions are subject to Act 127 which provides for preserving and managing the environment and air, water and soil quality. This act is subject to all types of industries and prescribed activities subject to section 34A of Act 127 and under Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 2015. However, for

the continuous monitoring of PM_{2.5} and PM₁₀ in the construction area, there is no specific legal provision stated in this act and order. DOE only issues Conditions of Approval (COA) based on the environmental impact assessment (EIA) report, environmental management plan and Director General's instructions to conduct continuous monitoring of PM_{2.5} and PM₁₀ in the construction area. Doe only issues conditional approval directives to projects subject to EIA only. Meanwhile projects that are not under EIA are not subject to these conditions and laws.

This also shows that Act 127 does not have any section or regulation that insists on continuous monitoring of PM_{2.5} and PM₁₀ in construction areas. For this reason, DOE enforcement cannot take arbitrary action on any project developer and project that is not subject to EIA and approval conditions under this Act. With this, PM_{2.5} and PM₁₀ emissions will be released into the atmosphere and continue to pollute it.

JKR Standard 3: 2020 Environmental Protection and Enhancement works for Projects had developed to improve technical instructions (Roads) 16/03 (amendment 2015) -A Guide for Environmental Protection & Enhancement Works under the Works Department of Malaysia that produce a comprehensive standard for environmental management that includes the design, planning, procurement and construction phases including building projects and infrastructure. This guidance taking into account legal and technical requirements while covering various external agencies in Peninsular Malaysia, Sabah and Sarawak. This document is supported by several other documents such as EIA, EMP and Land Disturbance Pollution Prevention and Mitigation Measures (LDP2M2). The JKR Standard 3 document also does not have enforcement or any document stated to be fined related to the absence of continuous PM_{2.5} and PM₁₀ monitoring at the construction site.

The solution to this matter, the proposal to establish a standard in the guidelines should be held to control the emission rate of PM_{2.5} and PM₁₀ into the air the proposal to establish a standard in the guidelines should be held to control the emission rate of PM_{2.5} and PM₁₀ into the air. The continuous monitoring of PM_{2.5} and PM₁₀ in construction areas is seen to be able to control the spread of PM_{2.5} and PM₁₀, very comprehensively and controlled. various suggestions are explained in chapter 6 for improvements to the study that covers the government and developers.

5.3 CONCLUSION

Through discussions and observations from this study, it was found that September is a very active month for PM_{2.5} and PM₁₀ emissions from the construction site. This was proven by the emissions of PM_{2.5} and PM₁₀ that exceed the Malaysia Ambient Air Quality Standard 2020. The activity in June and July seemed very slow at first, but when came to August, the activity in the study area became more active. The presence of PM_{2.5} can be seen by visually mapping the spread of PM_{2.5} using Rstudio which shows the spread of PM_{2.5} towards the north and surrounding area. This mapping shows that PM_{2.5} is able to spread far from the source of emission at the construction site. This spread is also helped by the presence of wind direction and wind velocity at a certain time and place.

The R studio analysis shows in Bivariate polar where the low mean concentration of PM_{2.5} (0 to 8 µg/m³) is distributed to RKKSHK and the Prison Penor Complex with wide range PM_{2.5} pattern dispersion. The low mean concentration is not as dangerous as the high mean concentration, but the pro-long exposure will cause an impact on receptors and may affect on health. However, the low mean concentration was shown widespread with the blue color presentation. The high mean concentration of PM_{2.5} above 11 µg/m³ was dispersed to the southeast and southwest of the construction site where most of the area is vegetation and plantation. The spreading of high mean concentration was far away from the sensitive receptor. The movement of PM_{2.5} was related to the direction of the wind and the speed of the wind where the result from WRPLOT supports the atmospheric situation in the research. \Construction activities are also one of the causes where activities that do not follow the planning schedule will increase the emission of dust (PM_{2.5}) into the air at a high rate.

Based on the absence of laws or regulations that involve continuous monitoring and require the monitoring of PM_{2.5} and PM₁₀ in construction areas, the government should take this matter seriously that the air pollution should be curbed from the source of emission. if the level of PM_{2.5} and PM₁₀ pollutants is already high in the atmosphere, it is difficult to contain and control the rate of spread because it involves the rate of wind speed and wind direction.

However, laws requiring continuous monitoring of $PM_{2.5}$ and PM_{10} should be enacted to control emissions from construction areas. The law will involve enforcement of developers who do not comply with the law and action can be taken for the offence committed. This matter needs to involve various government agencies that are directly involved in the construction sector.



CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 INTRODUCTION

This study shows that $PM_{2.5}$ and PM_{10} emissions from construction areas contribute to air pollution. Therefore, it is appropriate for us to protect our air from pollution and preserve this nature. Air pollution at construction sites is a significant environmental concern affecting workers on-site and the surrounding community. The construction industry is one of the largest contributors to air pollution, primarily due to machinery, dust, vehicle exhaust and other particulate matter. The most visible forms of pollution are dust ($PM_{2.5}$ and PM_{10}), which is generated from many construction sites sources. However, the impact of air pollutants may cause a serious issue that affects the health of local communities, workers and the environment.

6.2. SUMMARY OF FINDINGS

The primary objective of this research was to ensure that $PM_{2.5}$ and PM_{10} emissions are regulated at all times while construction is underway. For the time being there are no laws, guidelines, acts, or regulations that insist on the mandatory monitoring of $PM_{2.5}$ in construction areas. There are several developed countries outside that have activated the use of $PM_{2.5}$ monitoring in construction areas. However, it is not a continuous monitoring and it is only a periodic monitoring. Table 6.1 shows the summary of objectives, method, and significant findings that has been analyse, have analyzed, discussed, interpreted inspection data and collected information.

Table 6.1 Summary of findings.

NO.	OBJECTIVE	METHOD	SIGNIFICANT FINDING
1	Determine various concentrations of PM _{2.5} and PM ₁₀ emitted from the construction site activities	Monitor air quality at the site (PM₁₀ and PM_{2.5}): Aeroqual 500 Series	- September is the construction site's high PM_{2.5} and PM₁₀ concentration emissions. - The maximum PM_{2.5}: 38.65 µg/m³ (September), The minimum PM_{2.5}: 0.76 µg/m³ (November). - The maximum PM₁₀: 170.67 µg/m³ (August), The minimum PM₁₀ 2.29 µg/m³ (November). - PM_{2.5} concentration in September was above the Monthly PM_{2.5} MAAQS. - PM₁₀ concentration in August and September was above the Monthly PM₁₀ MAAQS.
2	Identify the sources/activities of significant components of PM _{2.5} emanating from a construction site.	Observation at the site.	- Movement of lorry, excavator, dumped truck, cars, - No earth cover plants applied at the site. - Do not comply with the speed limit instructions on the site - There is no phase-by-phase planning plan to open a new site.
3	Analysis of data collection using meteorological software and environmental modelling.	- Environmental, meteorological and statistical software: WRPLOT, Excel, Welch's T-Test and Rstudio software. - Comparison site data: Secondary data of the Department of Environment - Rstudio software	- Minimum temperature: 25.3°C (July), maximum temperature: 29.8°C (August). - Minimum Humidity: 75.1 RH% (August), maximum humidity: 93.2 RH% (November) - High average rainfall: 14.3 mm (November), lowest average rainfall: 2.6 mm (September). - WRPLOT: South wind blows 15% of the time with 0.5-2.10 m/s from June to October 2020.

			• RSTUDIO: South southwest wind carried 24% of PM_{2.5} with 5 to 10 µg/m³, East wind carried 18% of PM_{2.5} with 0 to 5 µg/m³.
4	Mapping the PM _{2.5} prediction dispersion on Google Earth for map visualisation.	• Analyse Rstudio Software • Analyse Earth Pro software (ggplot)	• The dispersion PM2.5 is mapping on the Earth pro. • Blue polar: 0 to 8 µg/m³ of PM_{2.5} distributed to the North (N), Northwest (NW), Southwest (SE), and Northeast (NE) areas in the range of 4 m/s to 18 m/s within 6 months. • Red polar: 12 µg/m³ of PM2.5 distributed to the Southeast (SE), Southwest (SW), South-Southwest (SSW), and South-Southeast (SSE) in the range of and above within 8 m/s to 18 m/s.
5	Gain recommendations and solutions from the research investigation done.	• Review government, board legislation, policies, act and guidelines	• In subchapter 6.4 the detailed recommendation is discussed and stated.

6.3 CONTRIBUTION OF THE STUDY

PM_{2.5} and PM₁₀ are parameters that can have an impact on human health. Prolonged cough, chest pain, asthma and cardiovascular are the effects on humans exposed to short and long periods. The dust that deposits leaves has effects on the plants. Two contributions can be given from this study, namely the theoretical rules contribution and the Rstudio Software methodology.

6.3.1 Theoretical Contribution

The findings of this study add to the literature review on the source of the pollution of PM_{2.5} and PM₁₀ from the construction site depending on the activities carried out in the construction area and the presence of wind velocity and wind direction crossing the construction area at the time. The activities such as land clearing, tree felling and site road construction contribute to the release of dust if it is not controlled. Those activities carried out in the construction area must be phased and the movement of activities monitored by the site supervisor at all times. In this way, activities that are seen to be able to release high dust are done at one time and other activities should be stopped temporarily. For example, when the truck is carrying sand or soil from outside to the construction area, any activity of opening the area/soil should be stopped temporarily to reduce the emission of dust in the construction area.

Second, the study confirms that the behaviour of drivers who do not comply with speed instructions in construction areas is one of the causes of PM_{2.5} and PM₁₀ emissions into the air. This attitude is difficult to see because it is from self-discipline. By giving a fine or not being allowed to operate can educate these truck drivers to be more disciplined by complying with the rules set. In addition, giving consolation prizes to prudent drivers in the construction area makes individuals comply with the rules and maintain driving etiquette.

Third, this study highlight that the developer plays a very important role in managing the construction area in a more orderly manner. The burden of air pollutant emissions should not be taken lightly because it involves the effects on human health

that will occur now and in the future. The developer should take action by suspending the operating license of stubborn drivers and management officers who do not comply with the construction schedule. Consistent schedule management will control the movement of activities and can help control the source of pollution.

Fourth, the study confirms that the absence of PM_{2.5} and PM₁₀ emission standards set in the construction area will further increase the emission rate of this parameter concentration. CIDB, DOE, JKR and PLANMalaysia agencies do not set mandatory conditions that must be followed by all developers. PM_{2.5} and PM₁₀ standards should be held to control the release of these parameters into the air. For now, the government does not take the monitoring of this parameter seriously, but it should not be dismissed because it has an impact on human health.

Fifth, the study reveals that enforcing the law in the continuous monitoring of PM_{2.5} and PM₁₀ should be implemented to ensure that air pollution does not occur and any source of emissions can be curbed. Improvements to laws and regulations should be implemented by various government agencies related to the construction sector. PM_{2.5} concentration should be monitored closely at the construction site as this fine particulate is available and able to transmit to other places with the existence of wind speed and wind direction. Currently, PM_{2.5} at the construction site is not continuously monitored by the developer and it is not a compulsory requirement monitored the air quality monitoring by the Construction Industry Development Board (CIDB), Malaysian Public Works Department (JKR), or Department of Environment (DOE). No documentation, statement, policy, or regulation stated that the air quality monitoring needs to be monitored continuously during the pre-construction phase, construction phase, and post-construction phase. These three phases involve the polluted air emission from the construction activities that may cause health complications to the workers and other people surrounding live near the project construction. Information from this study will be able to help the government and interested parties review standards and guidelines to align with national development and national physical plants. This study is also able to provide an overview of the impact on communities that will be affected by construction activities that are nearby or less than 500 meters from the border.

6.3.2 Methodology Rstudio Software

The study revealed the use of this software is increasingly important in mapping the air pollution that occurs around us. Rstudio is a software that can map the spread of pollution more clearly. There are not many users who use Rstudio because it involves a coding process that requires knowledge and skills in operating this software. Bivariate analysis in Rstudio needs a sufficient set of data and complete information to form a concise but cohesive presentation of information. Bivariate polar plots give a clear picture of the spread of $PM_{2.5}$. The bivariate polar used joint wind direction and wind speed to plot the data. The use of bivariate which is easy to understand as well as the use of Rstudio which saves costs should be used by developers. In this study it is seen very clearly the distribution of $PM_{2.5}$ is very clearly mapped on Google Earth. Several other studies use mapping techniques to compare information. However, the use of software that is similar like this requires a high cost to buy this software in the market. In addition, the use of this software requires a high RAM to cover its RAM capacity.

Rstudio and WRPLOT are free user and it is available on the open-source internet. The determination of pattern distribution using this software helps in understanding the pollution level across the different over time, area exposed, and various concentration exposure. The source of the air pollution contribution from construction sites can be identified to be monitored and control its emission to a low level of distribution. The pattern distribution helps us determine the mitigation method that should be applied at the construction site or change the schedule of construction management from time to time according to the high distribution of $PM_{2.5}$. The project developer can keep constant track of and monitor the pattern distribution of construction from time to time at different phases of construction activities. Rstudio is easy to use and it is available as opensource. The community can uses the software easily and it helps to know the level of pollution in the surroundings.

On 22 January 2019, a meeting between IIUM and the Construction Industry Development Board (CIDB) office headquarters under the Private and Corporate Sectors in Kuala Lumpur to discuss a proposal to apply the $PM_{2.5}$ and PM_{10} and continuously monitor at construction site in the CIDB standard document. However, the suggestion has to be rejected and no reason was given to us to contradict regarding to

proposal. Therefore, this research was evidence that $PM_{2.5}$ needs to be carried out during construction as $PM_{2.5}$ and PM_{10} can have a health impact on workers and surrounding recipients. $PM_{2.5}$ and PM_{10} is the dangerous forms of air pollution and cause serious and sometimes deadly illnesses.

DOE regulations such as *Environmental Quality (Clean Air) Regulation 2014* regulate the emission of air pollutants from industrial activities but not from construction activities. Under the CIDB standard document, the *Construction Industry Standard, CIS 17:2010 Guidelines for working at noisy and dusty areas in construction sites* stated that the total sampling of air monitoring is at least 7 hours and the monitoring should be repeated at least quarterly. Refer to the table particulate permissible exposure limit on an eight-hour-weighted average airborne concentration of the standard, the inhalable particulate not more than 10 mg/m^3 and respirable particulate is not more than 3 mg/m^3 refer to OSHA (Use and Standards of Exposure of Chemical Hazardous to Health Regulation 2000). According to the definition from CIS 17:2020, Inhalable dust is described as the size fraction of dust that enters the body, but is trapped in the nose in the nose, throat and upper respiratory tract and the median aerodynamic diameter of the dust is about $10 \text{ }\mu\text{m}$. The respirable dust is described to those dust particles that are small enough to penetrate the upper respiratory and deep into the lungs. The unit of inhalable and respirable particulates when converted to $\mu\text{g/m}^3$, indicates higher and over the MAAQS 2013 by value 2020 where the inhalable become $10,000 \text{ }\mu\text{g/m}^3$ and respirable become $4000 \text{ }\mu\text{g/m}^3$. The standard CIS 17:2010 needs to be viewed and reviewed according to current trends and situations. The standard does not comply with MAAQS 2013 and it is relevant to compare.

6.4 RECOMMENDATION IMPROVEMENT FOR CONSTRUCTION ACTIVITY

Various ways to overcome the problem of particulate matter emissions in construction areas. However, these steps must be implemented regularly and periodically throughout the construction. In addition, the willingness to comply with legal requirements is difficult to implement in most construction areas. This is because the law is considered frivolous by most construction workers and management at the construction site. Some recommendations are given to help the government in overcoming the problem of particulate matter emissions.

6.4.1 Set New PM_{2.5} and PM₁₀ in Legal Documentation, Law and Standard.

According to the document of *Arahan Teknik (Jalan) 16/03- Pindaan 2015, A Guide For Environmental Protection & Enhancement Works* by Malaysia Public Works Department amendment 2015 stated that the contractor shall carry out air quality of Total Suspended Particulates (TSP) for 24 hours not more than 260 µg/m³/day and Particulate Matter (PM₁₀) for 24 hours not more than 150 µg/m³/day. The parameters that are monitored in the document are larger aerodynamic diameters of more than 2.5 µm and different parameters. The PM₁₀ in Arahan Teknik is the only parameter that follows that MAAQS 2013 (2020) but the amount of PM₁₀ concentration is over the PM₁₀ concentration/day in MAAQS 2013 (2020). Table 6.2 shows none of PM_{2.5} is stated or required to be monitored in the document or regulation. This document is controlled by different agencies.

Table 6.2 Document and regulations that contain PM_{2.5} for monitoring air quality at the construction site.

Document/ Regulation	Pollutant/Chemical:	Averaging Time	Duration of air quality Monitoring
<i>Environmental Quality (Clean Air) Regulation 2014</i>	PM_{2.5}	None	None
<i>Construction Industry Standard, CIS 17:2010 Guidelines for working at noisy and dusty areas in construction sites</i>	Calcium carbonate, Calcium silicate, Emery, Gypsum, Limestone, Marble, Mica, Plaster of Paris, Portland, Ground granulated blast furnace slag and Pulverised fuel ash Coal dust PM_{2.5}	PEL 8 hour TWA (mg/m ³) Inhalable: 10 Respirable: 4 Respirable:2 None	Total sampling 7 at least hours and repeated quarterly. None None
<i>Arahan Teknik (Jalan) 16/03- Pindaan 2015, A Guide For Environmental Protection & Enhancement Works</i>	Total Suspended Particulates (TSP) Particulate Matter (PM ₁₀) PM_{2.5}	≤260 µg/m ³ /day ≤150 µg/m ³ /day None	24 hour 24 hour None

After reviewing government documents and literature on air quality standards, a suggestion to improve the Clean Air Regulation, CIDB standard document and Arahan Teknik to state and to conduct continuous PM_{2.5} concentration monitoring at the construction site as in Table 6.3 where it required to follow the Malaysia Ambient Air Quality Standard 2013 by 2020. There is no regulation that stringent the PM_{2.5} should be monitored daily and continuously at the construction site. The guidelines in CIDB, JKR, or DOE did not mention the requirement for monitoring and its importance in conducting a PM_{2.5} daily, quarterly, or yearly.

Table 6.3 Recommendation PM_{2.5} and PM₁₀ concentration into the regulation and document standard.

Pollutants	Averaging Time	Duration of air quality Monitoring
Particulate Matter with a size of less than 2.5 microns (PM _{2.5})	Annual:15 µg/m ³ 24 hour: 35 µg/m ³	24 hours
Particulate Matter with a size of less than 10 microns (PM ₁₀)	Annual:40 µg/m ³ 24 hour: 100 µg/m ³	24 hours

The monitoring of PM_{2.5} is done at the construction if it is required by the DOE requirements on certain projects that are significantly sensitive to cause an adverse impact on the environment. The various concentrations of PM_{2.5} showed that PM_{2.5} has possibly a high concentration of PM_{2.5} able to break out the standard of New Malaysia Ambient Air Quality Standard, above 35 µg/m³ as the number of activities rapidly occurred in the same month, time, and within the same area. The early stage/ phase of construction (consists of clearing, filling, excavation, etc.) is the mass production of particulate matter and this is an important part of intense control of the emission pollution at the source.

The dispersion of PM_{2.5} can remarkably disperse more than 1km of area depending on wind direction and wind speed at the current condition. Setting the concentration rate of PM_{2.5} and PM₁₀ in the construction area in the act and regulations will restrict the release of these pollutants and action can be taken against the developer. Focus group discussions (FGD) between enforcement agencies and developers regarding the establishment of laws can be conducted to obtain a consensus.

6.4.2 Compulsory to Monitor the Air Quality

By compulsory the implementation of air quality monitoring at the construction site, the volume emission of PM_{2.5} can be controlled and monitored by the developer. The construction phase plan can be organized and scheduled to the extent of referring monthly to yearly meteorological data and daily monitoring of PM_{2.5} emissions at the site. It is compulsory for any size of the area or quantum or any type of construction activity. In the construction industry, a Construction Industry Standard Guidelines For Working At Noisy And Dusty Areas In Construction Site CIS 17:2010 has already been developed by the Technical Committee on Occupational Safety and Health in Construction with moderator and facilitator by the Construction Industry Board (CIDB) Malaysia acted as assistance to technical committee in developing the standard. CIS 17:2010 is a guideline for protecting employees on construction sites. In the guideline, it is not compulsory for air pollution monitoring to be monitored by the developer at the construction site and this guideline does not rely on the New Malaysia Air Quality Standard 2020 (NMAQS 2020) as a reference.

There is no specific section in the Lembaga Pembangunan Industri Pembinaan Malaysia Act 1994 (Act 520) stated for environmental monitoring (water, air quality, etc) or fine stated under this Act for the emission of particulate matter, PM_{2.5}. Under the Department of Environment, the PM_{2.5} condition is stated in the EIA Condition of Approval (COAs) if the project is subjected to EIA only. In the Environmental Quality Act 1974 (Act 127), no section and regulation specific offenses on the emission of PM_{2.5} for the construction site. For JKR Standard, Environmental protection enhancement works for projects with document reference number JKR/SIRIM 3:2020 ICS:91.020; 13.020 stated that under the air quality monitoring, the PM_{2.5} monitoring is conducted throughout the project which complies with Recommended Malaysian Guidelines on Ambient Air Quality Standard 2020. However, the JKR/SIRIM 3:2020 is a voluntary document that depends on government agencies, professional bodies, associations, industries, regulators, etc. to adopt and use the standard. it is not a legal document.

6.4.3 Developing a PM Emission Inventory.

In Malaysia, we don't have any PM_{2.5} and PM₁₀ emission inventory on the construction site. Developing the PM_{2.5} and PM₁₀ emission inventory for the construction site will be the starting point to produce a Malaysian guideline for Particulate Emissions for Construction Sites. A site construction such as a highway, expressway, mix development, and industrial development will be selected to be a pilot project as these constructions are in large-scale, long-term development, large area involvement, involve sensitive environment (catchment area, mangrove area etc.) short and long term human adverse effect exposure. The PM_{2.5} and PM₁₀ emission inventory on the construction site will be used as a database in calculating and developing the standard for pollution of PM_{2.5} and PM₁₀ discharge from the construction site. The standard will be future-specific document references for construction developers in Malaysia.

If we refer to international documents such as the National Emissions Inventory (NEI) prepared by the United States Environmental Protection Agency (EPA) are an example of an emission inventory to tackle the significant source of air pollution. The NEI is used to identify the target regulatory action to be taken and also to promote public awareness concerning source emissions. The PM_{2.5} and PM₁₀ Emission Inventory can be used by DOE, CIDB, JKR and Local Authority to create better compliance value for standards and regulations.

6.4.4 Compulsory Providing the Compliance Air Quality Monitoring in Regulation

Currently, DOE, JKR, and CIDB do not have any expert or compliance in air quality monitoring that monitors the particulate matter emission at the construction site. None in CIDB guidelines, Arahan Teknik JKR and DOE stated to require a compulsory requirement to place the expert or compliance of air quality monitoring environmental officer in daily monitor the particulate matter within the construction time frame. DOE are the government agency that has the power to enforce and issue prohibition order or stop work construction if the construction is likely to cause damage to the environment. DOE only enforce the Environmental Quality Act (EQA 1974) regulation if the

construction was under Environmental Impact Assessment (EIA) and has an Environmental Management Plan (EMP), a list of the condition of Approval (COA) by DOE attached to the DOE license. If the construction doesn't fall under these requirements, therefore the construction is not tangible to any regulation act. In the worst case, the developer will avoid the emission of air pollution sources and the impact on the surrounding environment.

6.4.5 Compulsory Air Quality Modelling in Guidelines and Regulation

The modelling of air pollution becomes an important part of predicting the air pollution behaviour of dispersion patterns that emit from the construction site. Air modelling becomes an important reference to government agencies' technical meetings or EIA project meetings that involve mega-development projects, ports, agriculture, mining, new township, highland area and the construction of the dam. Air quality modelling can be used as a database and to create a better regulation act to be taken in advance. However, air quality modelling is not stated as compulsory in CIDB guidelines, Arahan Teknik JKR and not also stated in a section or regulation in EQA 1974. The air quality modelling is just an additional requirement upon request by DOE in the EIA meeting and it is not a compulsory requirement.

6.4.6 Land Use Information from the Government Agencies

Information on agriculture and non-agriculture land use can be obtained from the Department of Agriculture which collects and updates information on land use from time to time. The usage of this data in future research will provide real information department about the study and this will help the study to demonstrate the impact on the surrounding area. Other than that, this department also provide technical advice and consultation services that may help to clarify this study.

To obtain a more effective mapping in this study, the use of mapping information from the Department of Survey and Mapping Malaysia (JUPEM) can be utilised. Various service data such as surveying, mapping and geodata management

services can be found for this study. In addition, the map provided can provide a true picture and survey of the study area. Although it is quite difficult and time-consuming to obtain this information, it is worthwhile to obtain accurate and precise information.

6.4.7 Monitoring for 24 Hours Daily

Referring to Construction Industry Standard Guidelines for Working at Noisy and Dusty Areas in Construction Site CIS 17:2010, at least 7 hours of sampling time were recommended in the guidelines rather than 24 hours of monitoring recommended by NMAQS 2020. The 7 hours of monitoring are not enough to compare and to make the judgment that compliance of the construction site to the standard. The construction site that works for 24 hours, will follow the CIS 17:2010 guidelines, and only 7 hours of air monitoring were done. The guidelines should be reviewed and comply with the current standard air quality, methodologists and update new advanced technology applicable.

6.4.8 Addition of Point Data Collection

Further, the point data collection should be added and established to obtain more and more accurate with details coordinates information for this study. The data collection points should be placed around the study area and include all surrounding sources that are affected, such as residential areas and agricultural land. However, the placement of equipment at each data collection point should be considered in terms of safety and accessibility during the dry and rainy seasons.

6.5 LIMITATION AND FUTURE RESEARCH

Every research analysis has a constraint that we must face. The constraints that exist could be in the form of lesser impact or greater impact. It also can directly or indirectly have a potential impact that relates to environmental issues, legal, technical issues, etc. The constraints on the research are:

6.5.1 Political Issues due to Changes of Government.

In the year 2019, due to changes in political history in the government of Barisan Nasional (BN) to the new Pakatan Harapan (HR) caused, the stop of the construction of the project site was caused. The first research site where the research took place in conducting my research has stopped operation due to the stop of finances on the construction project. The project was under the federal government fund. The federal government has funded the construction project. Due to the critical situation, the developer of the project site must terminate my research monitoring. As the construction site was not in operation, and the construction site needs to be closed for no further notice.

6.5.2 Integrity Issues

After the termination from the first construction site, several letters has sending and emails to several developers in Kuantan and Kuala Lumpur to get a new place for me to start my research study again. The feedback response is that they did not trust the student's integrity and they did not want to share the possible data or construction progress with the study and academic researcher. They would not like to share any confidential data such as material building, financial data, or the progress phase of the construction to secure their construction site.

6.5.3 Technical Issues

The equipment for the research was not sufficient and it should be more than one equipment to conduct the research. As my research is self-funded, I lent the air quality monitoring equipment to a consultant company. They lent me the equipment during my research for 6-month period with charges. The equipment was quite expensive for me to buy. The Universiti Malaysia Pahang Al Sultan Abdullah (UMPSA) had the same equipment but the UMPSA is using the equipment for other universities' projects.

6.5.4 COVID-19 Pandemic

The presence of COVID-19 has caused restrictions on the study to be carried out in the construction area. various restriction rules by the government made this study have to shorten the monitoring from a year to 6 months. The inability to operate activities in the construction area during the pandemic caused the study area to be completely closed to workers and this study.

6.5.5 Lost of software

While correcting this thesis, this computer had a problem and had to be formatted. All software had to be deleted to format all windows, viruses, etc. The formatting process has caused the loss of data and information to process information. In connection with that, the process in Rstudio for the PM₁₀ parameter, it cannot be done and processed mapping can't be mapped.

6.5.6 Recommendation for Future Research

There are several gaps in our knowledge in research that follow from our findings, and would benefit from further research, including realist evaluation to extend and further test the theory we have developed here:

1. In-depth exploration, of the baselines project should be done in further research to set up the strict concentration standard of which is allowed to release of PM_{2.5} and PM₁₀ from the construction area to be used as a guidance document standard.
2. Research to develop approaches of cost-benefit analysis of measures to improve air quality in construction sites that could compare the damage and abatement costs in terms of concentration or emission release.
3. The involvement of the public and non-government agencies in research helps as a decision maker to influence the level and decision on the planning

of the construction schedule that involves a long period and massive construction.

4. A study on the preparation of a social impact report can be carried out to identify the level of impact of construction on the physical and mental health of the surrounding population. The health of the surrounding population is important because they are the only receptors who are exposed to air pollution directly from the construction site.
5. Conduct a complete and more extensive database for PM references from construction.
6. Research to develop the behaviour and origin of pollution sources from construction areas and non-fixed sources.

6.6 CONCLUSION

This study has proved September is the most polluted month and June is the cleanest month with the accumulative mean of the 24-hour concentration of $PM_{2.5}$ showing $19.51 \mu g/m^3$ and $2.34 \mu g/m^3$. During the daily sampling period, the most polluted day was in September with $38.65 \mu g/m^3$ and the cleanest day was in November with $0.76 \mu g/m^3$ respectively. Regarding the New Malaysia Ambient Air Quality Standard 2013 (MAAQS 2013) the daily concentration of $PM_{2.5}$ in several days in August, September, and October exceeded the daily average of $35 \mu g/m^3$ and an annual average of $15 \mu g/m^3$. The comparison standard was done daily and not yearly basis as the monitoring was done only six months monitoring. However, in the other 3 months (June, July and November) the $PM_{2.5}$ concentration did not exceed the MAAQS 2013.

In September, the study revealed that the mean temperature was $27.6^\circ C$, the mean humidity was 80.6% and the total rainfall was 2.6mm. This weather condition allows any activities to be carried out at the construction site. Activities such as clearing land, excavation, and filling are suitable in this weather condition. The moving vehicles that carry dirt on tires and the heavy transportation movement of the vehicles on unpaved roads cause particulate matter to disperse into the air. The Standard Deviation and minimum/ maximum value show the months of August, September, and October

2020 experienced high levels of PM_{2.5} emission. The confidence limit shows the 4.14 value of PM_{2.5} concentrations conquered in September.

September shows 17% of the days in the month are above the 24-hr PM_{2.5} value by 2020 in MAAQS 2013. The pattern distribution that PM_{2.5} in August (29%), September (60%), and October (26%) of the data set was above the annual PM_{2.5} value by 2020 of MAAQS 2013. Due to high temperatures, less rainfall and humidity, aggressive construction activities from all phases of construction occur at the site that contributes to the emission of PM_{2.5}. The emission of PM_{2.5} from construction site travels in airborne to other places with the presence of wind speed and wind direction that disperse the particulate from one place to another.

In November, the mean temperature was 26.3°C, the mean humidity was 86.5% and the total rainfall was 14.3mm. The weather conditions were mostly rainy days and it can be moderately intense or to be very intense. It is challenging to conduct an activity in the rainy weather which caused a lull in construction activities. The clearing of land, filling and excavation must be stopped work and this will delay the time progress period.

The study analysed that the use of WRPLOT showed that most of the wind blows from the south and south-southwest where the total wind speed is 15 m/s and 9.2 m/s. This is the highest wind speed captured during air monitoring and both winds blow to the north and north-northeast. This software only stimulates the wind speed and wind direction with the other meteorological data. WRPLOT is user-friendly and it is easy to create plots with a simple command and intuitive controls. This software is not as hard to learn and it is flexible to be used on any type of computer.

Rstudio stimulates the dispersion of PM_{2.5} with wind speed and wind direction together. The Rstudio showed that the wind blows PM_{2.5} to the north, northwest, northeast and slightly to the southwest with wind speeds in the range of 4 m/s to 18 m/s respectively. About 24% of PM_{2.5} concentration was blown by the south-southwest wind and 18% was blown by the East wind. Rstudio is a more powerful tool as it can combine three parameters to stimulate better and more virtuous results compared to WRPLOT.

The PM_{2.5} concentration dispersion is shown in Rstudio as a bivariate polar plot through modelling calculation. The result illustrates the blue polar is the largest portion distribution with 0 to 8 µg/m³ of PM_{2.5} distributed to the north, northwest, northeast and slightly to the southwest with 4 m/s to 18 m/s. The second largest portion distribution is the light blue polar with 8 µg/m³ to 9 µg/m³ blown to the west, south and east with 6 m/s and 14 m/s. The red polar is the third largest with above 12 µg/m³ that blows toward southeast, southwest, south-southwest and south-southeast with 8 m/s to 18 m/s.

In the stimulation of Rstudio, the wind blew the PM_{2.5} concentration, blue to the north where Rumah Kanak-Kanak Sultan Hajjah Kalsom (RKKSHK) and Penor Prison Complex were located. The RKKSHK is adjacent to the site construction and only a fence acts as the border and barrier of both areas. The PM_{2.5} concentration that was blown to the area is less than 8 µg/m³. This shows that the wind speed and wind direction in this particular area can transport less than 10 µg/m³ of PM_{2.5} concentration to RKKSHK. The wind speed and wind direction can't be controlled by humans or other mechanical equipment as it is the natural movement of air in any direction.

This study shows that WRPLOT can provide a clear visual representation of wind velocity and direction. WRPLOT software, the wind roses petal that consists of wind direction and wind speed can be exported directly to Google Maps. The function is easy to understand, practical, adaptable and convenient to transfer the windrose. No coding is needed as the function export is already provided by the programmer. Difference to Rstudio, the package function known as **polarmap** needs to be installed from GitHub because the function is not available in CRAN. It is troublesome with Rstudio where some functions are not available in the package. Both results from the tools can be used together to produce better results and mapping. The source of emission is the only thing that humans can control and organize to reduce the impact of emission. The meteorological data is important data to predict or forecast the activities that can be conducted periodically at the construction site. Therefore, an organized and more efficient work practice at the construction site would be applied. Rstudio is a free user and the tutorials on YouTube are available to be accessed by anyone willing to learn Rstudio coding and many websites that give tips and formulas to run the Rstudio.

This study has many loopholes in terms of law and stress in managing planning in construction areas. The non-continuous monitoring of $PM_{2.5}$ and PM_{10} makes the concentration rate of these parameters increase in the air. This matter can be curbed if the government insists on continuous monitoring and sets strict standards for $PM_{2.5}$ and PM_{10} emissions held in the construction sector. The industry and interested parties should take mitigation measures capable of reducing the impact and self-regulation should be fully practised.



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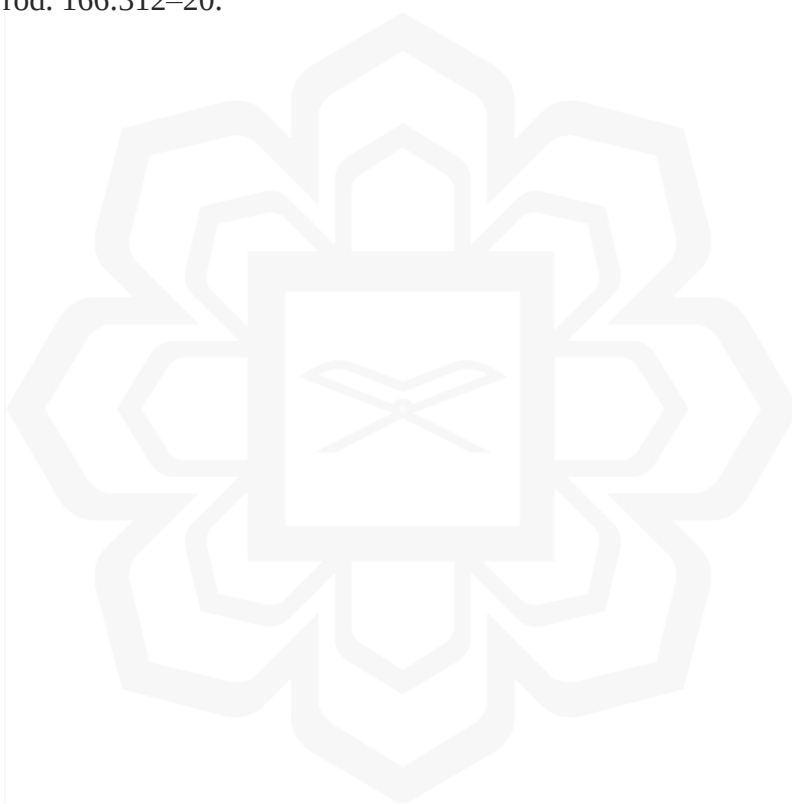
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APPENDIX A: PRIYA CONSTRUCTION PLANNING DESIGN

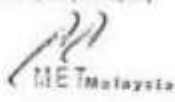


APPENDIX B: LETTER TO GOVERNMENT AGENCY



JABATAN METEOROLOGI MALAYSIA
SEKSYEN IKLIM & HIDROLOGI
JALAN SULTAN, 46067 PETALING JAYA
SELANGOR DARUL EHSAN

KP-1/92 (Pin. 1/07)



BORANG PERMOHONAN DATA / MAKLUMAT METEOROLOGI
(DATA / METEOROLOGICAL INFORMATION APPLICATION FORM)

Nama (Name): Putri Shazwa Rahman No. Kad Pengiraan: 800319-01-6094
 Agensi/Peringkat (Agency/Company): Universiti Islam Antarabangsa Malaysia
 Alamat (Address): No 24, Lorong Bandar Rima 1/3, Bandar Rima, 26060 Kemaman
 No. Telefon (Tel No.): 0176360255 Faks (Fax): _____ E-mel (Email): putrishazwa@ump.edu.my

Data-data/Maklumat Meteorologi yang dipohon:
(Data/Meteorological Information Requested)

Jenis Data/Maklumat (Types of Data/Information)	Kawasan (Area)	Tempoh Masa (Period)	Data Yang Dibekalkan (Untuk Kegunaan Pejabat) (For Office Use Only)
<u>Data from June - October 2020</u>			
<u>Rainfall (Hourly)</u>	<u>Stesen Kuantan</u>	<u>June - October 2020</u>	<u>Off-kuantan</u>
<u>wind speed (hourly)</u>			<u>Off-hourly < RR</u>
<u>wind direction (hourly)</u>			<u>Jun - Okt 2020 (Fm-hr)</u>
<u>temperature (Daily)</u>			<u>RM 1,200</u>
<u>Humidity (Daily)</u>			<u>Off-daily < 24hr max-T</u>
			<u>RM 40</u>

Tujuan data/Maklumat diperlukan: Kajian Intercultural Worker bagi Post-graduate UAM research
(Purpose of data/information needed)

Ke maklumat/data ini diperlukan bagi tujuan penyelidikan atau menjalankan projek, sila nyatakan dengan terperinci:
(If the data/meteorological information is for research purposes, please list the details:
The objective, scope, project background and research methodology
I have attached the letter of authorization from the Dean or Head of Department)

Tarikh Permohonan: 17/8/2020
 (Date of Submission)


 Tapdatang Permohonan
(Applicant Signature)

* No. inport: 203-20390

UTUK KEUPAAN PEJASAT
(For Office Use Only)

MAM.COM31/309 : _____ a) Pekhidenan : RM <u>1,240.00</u> € Harganya sudah Tunai/Cash/Crimal Wang* to. Rekt : _____ Bertulis : _____ ayuan diterima dan direkod oleh : _____	Pegawai yang Meluluskan Permohonan :  <u>19/8/20</u> Data/Maklumat dibekalkan oleh : <u>(B)</u> Catatan : <u>(NR)</u>
---	--

APPENDIX C: LETTER TO DEVELOPER

 الجامعة الإسلامية العالمية ماليزيا INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA جامعة إسلامية انتارابangsa ماليزيا Center of Knowledge and Ethics PREMIER INTERNATIONAL ISLAMIC RESEARCH UNIVERSITY		APPENDIX C
KULLIYAH OF SCIENCE		
Pengurus Projek Kencana Amanjaya Sdn Bhd E-1-08, Capital 5, Oasis Square No.2, Jalan PJU 1A/7A Ara Damansara 47301 PETALING JAYA		5 Februari 2020
Tuan,		
MEMOHON MENJALANKAN KAJIAN KUALITI UDARA <i>PARTICULATE MATTER</i> (PM2.5) DI KAWASAN PEMBINAAN PROJEK PRIYA RUMAH IDAMAN, DI LOT 8094, MUKIM PENOR, DAERAH KUANTAN, PAHANG		
Merujuk kepada perkara tersebut di atas.		
2. Saya, Dr Mohd Armi Bin Abu Samah, Penolong Profesor Universiti dan Penyelia kepada pelajar bernama Putri Shazlia Binti Rosman, No Matrik G1726474, merupakan pelajar Jurusan Doktor Falsafah Biosains di Kulliyah of Scinces, Universiti Islam Antarabangsa Malaysia (IIUM) Kampus Kuantan. Beliau sedang menjalankan kajian pemantauan terhadap kualiti udara iaitu <i>Particulate Matter</i> (PM2.5) dari aktiviti-aktiviti yang dijalankan di dalam kawasan pembinaan. Tema kajian beliau adalah <i>Particulate Matter (PM2.5) Emission at Construction Area In Kuantan</i>. Kepentingan kajian ini adalah untuk mengukur tahap penyebaran <i>particulate matter</i> (PM2.5) yang terhasil dari aktiviti-aktiviti di kawasan pembinaan dan memetakan penyebaran PM2.5 menggunakan <i>software</i> terkini bagi melihat corak penyebaran PM2.5 tersebut. 3. Untuk makluman tuan, beliau adalah pelajar tahun dua (2) di universiti IIUM dan beliau merupakan seorang pensyarah di Fakulti Teknologi Kejuruteraan Awam (FTKA) di Universiti Malaysia Pahang (UMP). Beliau juga pernah berkhidmat di Jabatan Alam Sekitar selama tujuh (7) tahun. 4. Untuk makluman tuan, kajian pemantuan PM2.5 hanya mengambil masa selama enam (6) bulan sahaja dimana alat kualiti udara dan alat pengukur cuaca (<i>weather station</i>) akan dipasang di dalam kawasan pembinaan. Pemantuan PM2.5 ini adalah 24 jam dan data akan diberikan secara percuma kepada pihak tuan. Data PM2.5 ini hanya akan digunakan untuk tujuan kajian universiti ini sahaja dan tidak akan digunakan untuk sebarang tujuan lain. 5. Sehubungan dengan itu, pihak kami berharap agar pihak tuan dapat mempertimbangkan permohonan ini. Sekiranya pihak tuan mempunyai sebarang pertanyaan boleh menghubungi Putri Shazlia Binti Rosman di talian 017-636 0255 atau emel kepada putrishazlia@ump.edu.my.		
   Office Address: Kulliyah of Science, IIUM Kuantan Campus, Jalan Sultan Ahmad Shah, Bandar Indera Mahkota, 25200 Kuantan, Pahang. Tel: +609-570 4000 Fax: +609-571 5781 Website: www.iium.edu.my/science		

APPENDIX C1

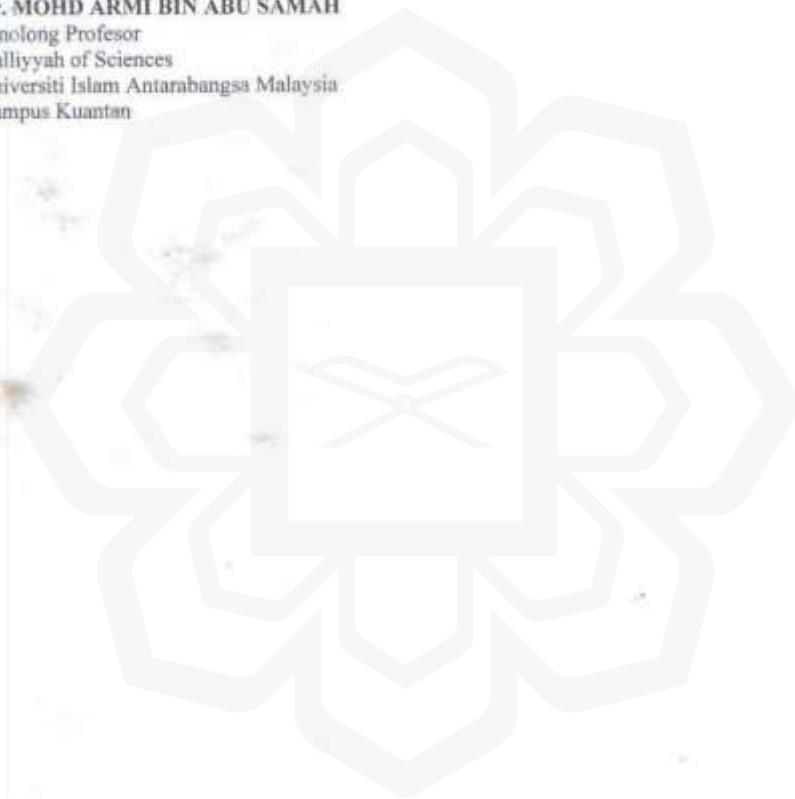
-2-

Kerjasama dan pertimbangan tuan dalam perkara ini amatlah dihargai dan didahului dengan ucapan terima kasih.

Sekian.



Dr. MOHD ARMI BIN ABU SAMAH
Penolong Profesor
Kuliyah of Sciences
Universiti Islam Antarabangsa Malaysia
Kampus Kuantan



CENTRE FOR POST GRADUATE STUDIES

Our Reference : IIUM/503/REG/13/9/2/5

Date : February 5, 2020

Pengurus Projek
Kencana Amanjaya Sdn Bhd
E-1-08, Capital 5, Qasis Square
No.2, Jalan PJU 1A/7A
Ara Damansara
47301 PETALING JAYA

Dear Sir/Madam,

CERTIFICATION LETTER

This is to certify that the below name is a postgraduate student at the International Islamic University Malaysia. The details of the student are as follows :-

MATRIC NO	: G1726474
NAME	: PUTRI SHAZLIA BINTI ROSMAN
NRIC NO/PASSPORT NO.	: 800319016094
NATIONALITY	: MALAYSIA
KULLIYAH	: KULLIYAH OF SCIENCE
PROGRAMME	: DOCTOR OF PHILOSOPHY (BIOSCIENCES)
PROGRAMME MODE	: RESEARCH
PROGRAMME DURATION	
MINIMUM	: 3 YEARS
MAXIMUM	: 6 YEARS
ENROLMENT DATE	: 05/02/2018 (SEM. 2, 2017/2018)
CURRENT CANDIDATURE	: 4 SEMESTER(S)
EXPECTED END DATE OF STUDY	: FEB-2021

This university uses English language as the medium of instruction.
Any assistance rendered to him/her is greatly appreciated.

Thank you.

CENTRE FOR POSTGRADUATE STUDIES
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

This letter is valid for three months only after being issued. It will be automatically invalid once the student is suspended /

APPENDIX D: ACHIEVEMENTS





الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
وإنسبى الشارح الشارح الشارح
Caden of knowledge and life
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THESIS
FOUNDED BY THE UNIVERSITY OF QUEENSLAND

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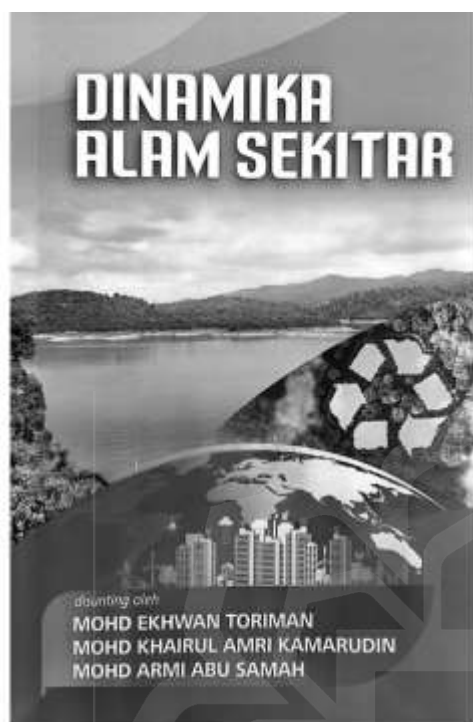
SR. PUTRI SHAZLIA BINTI ROSMAN
(G 1726474)

for the outstanding achievement in the
3-MINUTES THESIS COMPETITION
Kulliyyah of Science
International Islamic University Malaysia
27th February 2020

ASSOC. PROF. DR. NORMAWATY MOHAMMAD NOOR
DEPUTY DEAN (POSTGRADUATE & RESEARCH)
KULLIYAH OF SCIENCE
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

PROF. DR. SHAHBUDIN SAAD
DEAN
KULLIYAH OF SCIENCE
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

APPENDIX E: PUBLISHED WORKS



DINAMIKA ALAM SEKITAR

disunting oleh
MOHD EKHMAN TORIMAN
MOHD KHAIRUL AMR KAMARUDIN
MOHD ARMI ABU SAMAH

PENERBIT UNIVERSITI KEBANGSAAN MALAYSIA
BANGI • 2023
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 PERSATIAN POWDERMAN BUKU MALLAY /
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 No. 44 / Montecito No. 19191

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JALAN CENDANA BUKIT, SELATAN DAUD KHAYU, MALAYSIA

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 No. 270, Jalan Pura 8
 Taman Kajang Pura
 43000 Kajang, Selangor (Dated Stamp, MALAYSIA)



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ISBN 978-929-7547-55-9

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Particulate Matter (PM 2.5) At Construction Site: A Review

Putri Shazlia Rosman, Mohd Armi Abu Samah, Kamaruzzaman Yunus,
Mohd Ramzi Mohd Hussain

ABSTRACT—In Malaysia, construction sector growing 8% to RM170 billion in 2017, 8.2 % or RM140 billion in 2015 and 7.4% t or RM166 billion in 2016. Construction activities at all phases of construction from land clearing to building structure generate particulate matter emission (PM) that causes health impact to human and environment. Many researchers have done to identify and classified the particulate matter from its source of origins emissions at construction site. PM2.5 is a fine particle is potential to enter lung and bloodstream and lead to death. The objective of this paper to identify the potential of PM2.5 release at construction site, effect to receptor who exposed to it and determine the other factor that contribute to distribute the PM2.5 at construction site. The construction activity proved to cause PM2.5 emission effect to human health and environment. Though, meteorology such as wind direction, temperature, humidity, pressure, wind speed not only factor need to be considerate that influences the distribution dispersion of PM2.5 but other factor such as chemical formation, dispersion process and removal mechanism need to be measured. CDC 2013 studies, showed every PM2.5 decreases of 10 ug/m³ of air it will decrease 15% in the risk of heart disease deaths. Malaysia showed the annual mean concentration of fine particulate matter in urban areas was exceeding the WHO air quality guideline with 17.3 ug/m³. The construction site needs to control and monitored its emission of particulate matter by having a proper schedule construction time management and modeling the distribution of PM2.5 at site.

Keyword: PM2.5, construction activities, meteorology, health effect

I. INTRODUCTION

People breathe air freely every day without paying any cost that they inhale. It has because the air is available in atmosphere where we just breathe in. But what if the air that we breathe is polluted with toxic, bacteria and fungi for several days, months or maybe years? Do you concern the pollution from construction and how these pollutants occur to your nearby home? You can see, dusts were generating from the construction activities from your naked eyes, but do you know that these dusts can cause health impact to human and environment, partially or wholly. The emission of air pollutants from construction equipment is the main environmental concern because it may impact air quality as

well as health of construction workers and climate change. In these paper reviews, we will discuss the type and source of construction activities that generate the particulate matter PM2.5 from the construction activities that cause seriously health impact to human and environment. PM also causes adverse impacts to the environment such as climate impacts, visibility impairment, ecological effects and effects on materials (e.g building surfaces).

II. PM2.5 POLLUTED CITIES AND GLOBAL EPISODES.

According to the global air pollution database that released in Geneva by World Health Organization (WHO) dated on May 2, 2018 reveal that India has 14 out of the 15 in terms of PM2.5 concentration have most polluted cities in the world. In between year 2010 to 2014, the pollution level was improved but in year 2015 the pollution level in

Recently, deteriorations have been reported in Delhi. Specifically, a 2016 report by the World Health Organization reveals that the region has witnessed the rate of annual pollution, on average, stand at 143 µg/m³. Indeed this figure is thrice the expected national standards. In 2019, Thailand's situation indicated that in Chang Mai, air pollution has been dominant in the last decade [1]. As such, many individuals have continually inhaled particulate matter, which originates from smog in the atmosphere. One of the lectures in the Faculty of Medicine (In Ching Mai University) < Dr. Chaicham Pothirath, acknowledges that the exposure to particulate matter accounts for the rising cases of death, hence a high mortality rate in the region. Regarding PM2.5 dust particles, some of the health conditions that they cause, if inhaled for a significant period, include lung inflammation, heart disease, lung cancer, and stroke. Hence, the health conditions account for a significant reduction in life expectancy [1].

III. MALAYSIA PLAN IN CONSTRUCTION

Eleventh Malaysia Plan 2016-2020, the development of infrastructure highly progressive occurred now in numerous mega infrastructure projects such as Refinery and Petrochemical Integrated Development project in Johor, Mass Rapid Transit Two in Klang Valley, and the Pan Borneo Highway connecting Sabah and Sarawak. The Central Spine Road, which connects Kuala Krai to Simpang Pelangai Pahang, and Kota Bharu-Kuala Krai Highway that construct for better connectivity people in west to east coast

Revised Manuscript Received on May 15, 2019.

Putri Shazlia Rosman, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Faculty of Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Pahang, Malaysia (marini@iium.edu.my)

Mohd Armi Abu Samah, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang, Malaysia

Kamaruzzaman Yunus, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang, Malaysia

Mohd Ramzi Mohd Hussain, Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia, Gombak, Selangor.

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255

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A Research on Concentration and Distribution of Airborne Particulate Matter in Kuantan City

Putri Shazlia Rosman, Mohd Armi Abu Samah, Kamaruzzaman Yunus

ABSTRACT— The development of Kuantan city had caused a great emission of particulate matter concentration to the Kuantan atmospheric. The airborne of particulate matter may causes immediate and long-term impacts on human health as it enters the lung through the respiratory tract. The larger particles more than 10 μ m aerodynamic diameter can found in soot or smoke. In this study, the concentration of particulate matter (PM10) in the ambient air of Kuantan city was investigated using two continues monitoring station by the Department of Environment. The PM10 data were taken for 15 years of study from year 2001-2016. Two (2) location of the continues monitoring station were used in the study where one in Indera Mahkota, Kuantan and another was in Balok Baru, Kuantan. In the study, the highest PM10 concentration was in year 2013 with 234.31 μ g/m³ and the second highest in year 2015 with 271.62 μ g/m³ for station 1. While, for station 2 the highest PM10 concentration were in year 2013 with 349.7 μ g/m³ and the second highest in year 2015 with 328.46 μ g/m³ respectively. The pattern distribution showed that the PM10 concentration between year 2013 to 2015 were absolutely outrages which was more than 300 μ g/m³ was release in the atmospheric. The sources emission factor in this study can be from various sources and trans-boundary events may also be possible to cause the PM10 concentration disperse in Kuantan.

Index Terms— Aerodynamic, atmospheric, emission, monitoring, pattern.

I. INTRODUCTION

Kuantan is a capital state of Pahang that still maintain its natural environment. In Kuantan district, there are waterfalls, seas, hills and many ecotourism places like Panorama Hills, Bukit Pelindung, Rainbow Waterfall and Chempedak Beach that offers attraction to many tourists to come and explore here. Despite, maintaining its beautiful nature, the needs of development to achieve sustainable city and increased economic growth for people of Kuantan, many constructions of infrastructure were done. Many shopping malls such as East Coast Mall, Kuantan City Mall, Berjaya Mall and Kuantan Parade come heaven place for shoppers that visited Kuantan. Therefore, more development being carried by the local authority to bring up Kuantan city as the best city to be stay in the East Coast State. Despite that to improve Kuantan city to become more lively, attractive urban center and high harmonious the quality of life style citizen that live here.

However, the air pollution from the development during construction to the turn the view of the city become cause

serious issues to Kuantan citizen. In this study. We will understand the pattern distribution of PM10 since 2001 until 2016 the development of the Kuantan City. Many sources factor of pollution may contribute to the emission of the particulate matter. But, most of the emission particulate matter will be in short time period and will not last longer. These is due to the time frame of the construction activities take part. Other emission could cause from other such as mobile sources (car and lorry) or from different industrial emission. The unplanned and uncontrolled development of industrial premises could lead to higher emission [1].

A. Particulate Matter (PM10)

Particulate matter is a physical classification of particulates that found in soot, smoke, dust, dirty and liquid droplet. Particulate matter is a mixture of particulates from different composition, properties, sizes, and sources [2], [3]. Due to the mixture of aqueous and solid particulate, particulate matter can enter the atmosphere by natural and anthropogenic pathways [3]. The activities such as process heaters, vehicle exhaust, large boilers and incinerators from industrial combustion produce particulate matter. Particulate matter can be emitting directly into the air from stone crushing, wood burnings, unpaved roads, construction sites and factories. The sizes of PM10 are smaller than 10 micrometers in diameter but larger than 2.5 micrometers.

PM10 was recorded as one of the air pollutants concentration limits in New Malaysia Ambient Air Quality Standard. New Malaysia Ambient Air Quality Standard is a new standard to replace the Malaysia Ambient Air Quality Guidelines that has been used since 1989. In the new standard there are three (3) interim targets set for PM10 that are IT-1 until year 2015, IT-2 until year 2018 and the ambient air quality standard will be full implementation on year 2020. Each concentration for the interim target is different according to the year target. For IT-1 (2015) for averaging time for 1 year is 50 μ g/m³ and 24 hours is 150 μ g/m³, for IT-2 (2018) for 1 year 45 μ g/m³ and 24 hours is 120 μ g/m³ and for year 2020 for 1 year is 40 μ g/m³ and 24 hours is 100 μ g/m³.

According to the previous studies the best indicator for the ambient air pollution is the PM [4]. The dangerous of PM10 could cause respiratory health risk through inhalation if it deposited at the thorax (bronchial, trachea and alveolar regions) pose greater risk [5]. Particulate matter can cause serious health problem and it can also cause morbidity and mortality to human being [6], [7].

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Putri Shazlia Rosman, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang, Malaysia.

Mohd Armi Abu Samah, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang, Malaysia.

Kamaruzzaman Yunus, Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang, Malaysia.

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Quality Air Monitoring Equipment: The Review Of Air Quality Monitoring Equipment

Putri Shazlia Rosman^{1,2}, Mohd Armi Abu Samah¹, Kamaruzzaman Yunus¹, Mohd Ramzi Mohd Hussain³, Mohd Zikri Azmi⁴

1. Kulliyah of Sciences, International Islamic University Malaysia, Indera Mahkota, Kuantan, Pahang
2. Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Malaysia
3. Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia, Gombak, Selangor
4. Enviroconsult Services, No.24, Lorong Bandar Putra 1/8, Bandar Putra, 26060 Kuantan, Malaysia

*Correspondence should be addressed to Putri Shazlia Rosman; putrishazlia@iium.edu.my

Abstract

Air quality is one of the important elements in environmental monitoring such as water quality and noise level monitoring. The result from the in-situ experiment would give direct reading on current existing environment on any propose study area. Nowadays, the invention of air quality equipment is easy to be handle, hand-held, portable and convenience to bring to niche or impossible area to fits in by human. With long life battery allow it operate for 24 hours at field and many divines gases can be monitor with single head. The purpose of the study was to review the equipment that used for air quality monitoring that capable to gives real time reading, cost effective equipment and portable to monitor at site. In this study, Aeroqual Series 500 is an air quality monitoring equipment was used to monitored the PM_{2.5} and PM₁₀ at three different site studies. The Series 500 air quality is portable handheld monitor and enables to give accurate real time data ether deployed for short term fixed monitoring. The site studies were selected by the environmental consultant to be reviewed. The result of the air quality was accurate in real time respond to monitor air quality. However, another factor such as meteorology condition and topography, slope gradient and land use factor need to be considered to place the equipment in order to avoid any undesirable reading and missing data.

Keyword: Aeroqual, PM_{2.5}, PM₁₀, air quality monitoring

Abbreviations:

PM_{2.5} -particulate Matter 2.5
PM₁₀ = Particulate Matter 10
ST = Air Quality Station

Introduction

Air quality nowadays is an important issue for all human in planning their activities for the days ahead. People now aware the status of the air quality around them and if the air quality are polluted, they will try to get the air quality reading from the government meteorology or from the authorities' government website. However, people who really concern about the air quality around them, they willing to buy the air quality equipment that sold in the market with reasonable price and real time air quality data. The presence of undesired material in air, in huge quantities able to produce harmful effect. The excessive substances including particles, gases and biological molecules. The air pollution may damage human property, vegetation, human health or form hazy and produce unpleasant smell. Measures the air pollution help to determine the level of air pollutants that stay in our atmosphere.

To measure the air quality, must have the best quality air monitoring equipment. The air quality equipment is a diagnostic instrument/tool to measure the level quality of air pollution at surrounding. The device can be place either permanent at one place or portable. It is important to find instrument that meet the various industry standard with better price and meet their requirement



UNIVERSITI MALAYSIA KELANTAN

Kampus Jeli, 17600 Jeli, Kelantan, Malaysia.

www.umk.edu.my

Tel : 09-9477200/7406

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Faculty Of Bioengineering And Technology

RUJ. KAMI (Our Ref.): UMP01

TARIKH (Date): 28th May 2023

Mrs. Putri Shazlia Rosman
UNIVERSITI MALAYSIA PAHANG
Email: putrishazlia@ump.edu.my

Dear Mrs. Putri Shazlia Rosman,

LETTER OF ACCEPTANCE

The organizing committee is delighted to announce that your abstract has been accepted for presentation at the International Conference of Bioengineering and Technology 2023 (IConBET2023), scheduled for August 29th and 30th, 2023. Please find the details of your presentation listed:

Presentation title : ***Particulate Matter (PM2.5) Dispersion Pattern at Selected Construction in Kuantan Pahang: Environmental Management Modelling***

The reviewers have recommended that you can submit the full manuscript. As such, we request that you prepare and submit the full manuscript while ensuring strict compliance with the specified formatting guidelines in the template available on the information page.

We would like to advise that the submission of full papers must be done via the IConBET2023 website at iconbet.umk.edu.my. The required file format for the submission is MS Word, with **only ONE file** permitted **per submission**. Please note that each registration is limited to the submission of a single full paper, with the article length being limited to **5-6 pages**. All papers will be published in a **Scopus-indexed journal**.

If you have any further questions or concerns, please do not hesitate to contact us by emailing iconbet@umk.edu.my. We are happy to assist you in any way we can.

We are eagerly anticipating your presence at IConBET2023. Thank you in advance.

Yours Sincerely,

ASSOC. PROF.DR. MUHAMMAD AZWADI BIN SULAIMAN
Dean,
Faculty of Bioengineering and Technology

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APPENDIX F: RESEARCH PICTURES



Figure 1. Bandar Baru Kuantan Puteri Residential



Figure 2.Sg Soi Residential



Figure 3. Smallholder agriculture



Figure 4. Kg Pahang Kuantan



Figure 5. Komplek Asnaf Majlis Ugama Islam Pahang



Figure 6. Oil palm plantation



Figure 7. Penor Prison



Figure 8. Entrance to Penor Prison Mosque



Figure 9: Rumah Kanak-kanak Sultanah Hajjah Kalsom

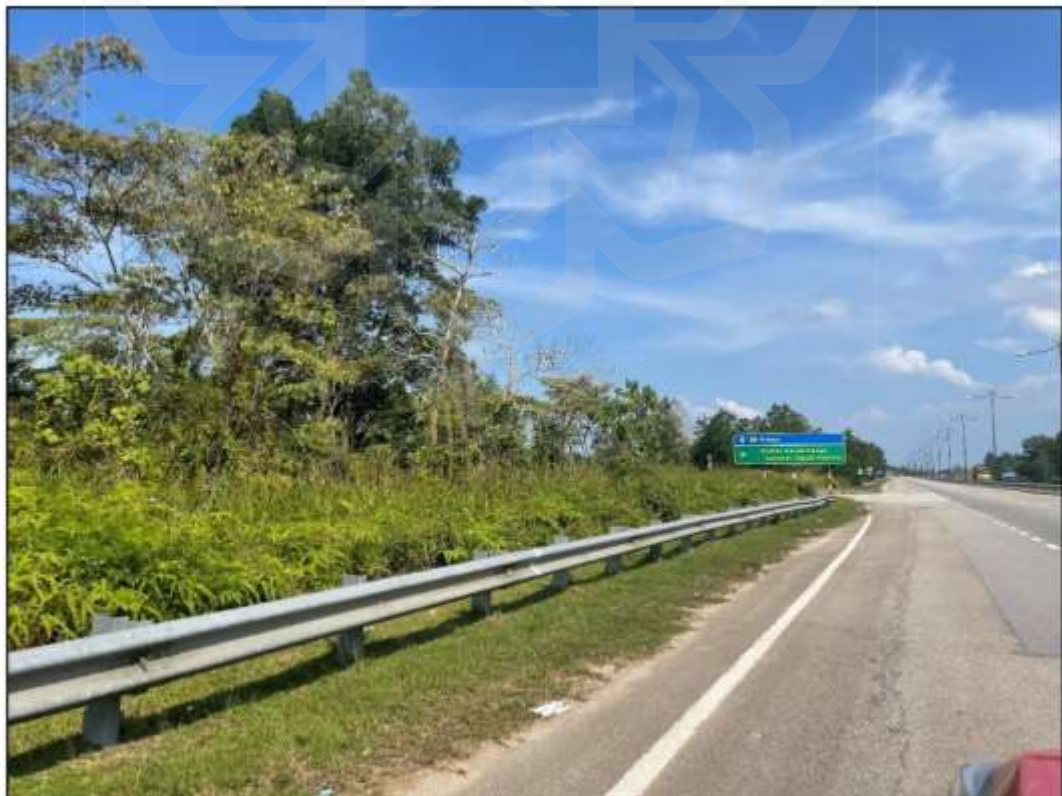


Figure 10. Entrance to Rumah Kanak-kanak Sultanah Hajjah Kalsom



Figure 11. Priya Housing Advertising



Figure 12. Peat soil and bushes



Figure 13. Prohibition Order on Open Burning on peat soil



Figure 14. Cover lid equipment broken



Figure 15. Aerial view Priya construction site 1



Figure 16. Aerial view Priya construction site 2



Figure 17. Aerial view Priya construction site 3



Figure 18. Aerial view border Priya and Rumah Kanak-kanak Sultanah Hajjah Kalsom



Figure 19. The boundary between the construction area and the Rumah Kanak-kanak Sultanah Hajah Kalsom



Figure 20. Aerial view of bushes and peat soil surrounding Priya's construction

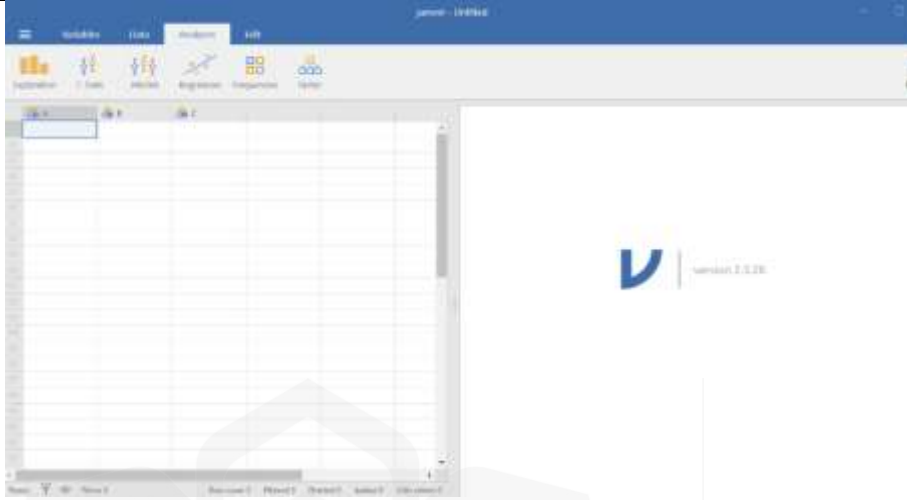
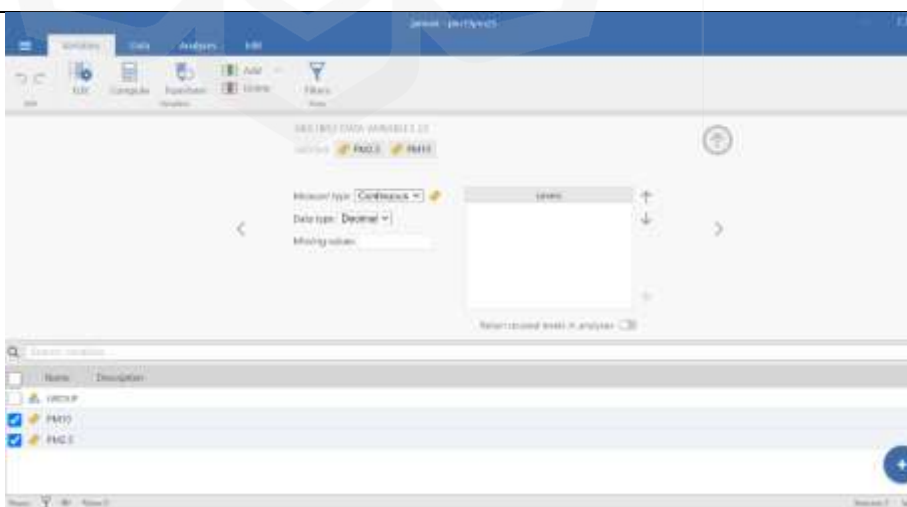


Figure 21. Aerial view of Rumah Kanak-kanak Sultanah Hajjah Kalsom

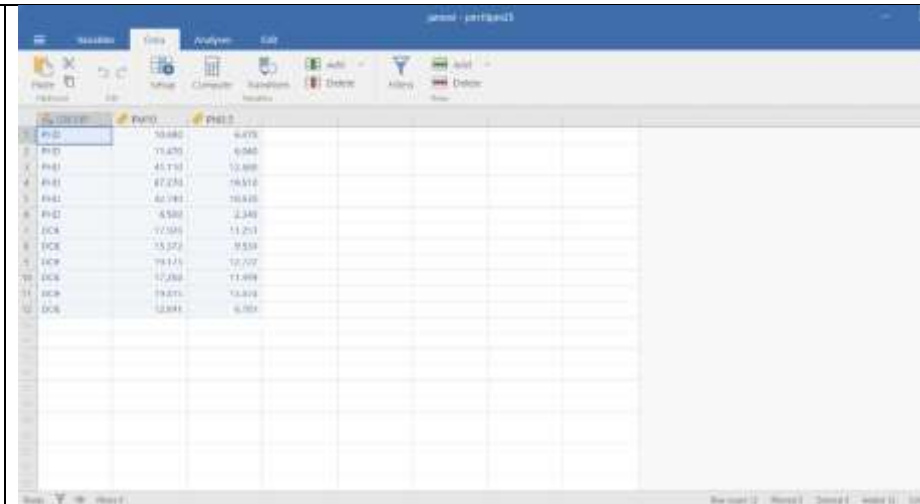


Figure 22. Sekolah Kebangsaan Seri Melati, Kuantan

APPENDIX G: WELCH'S T-TEST

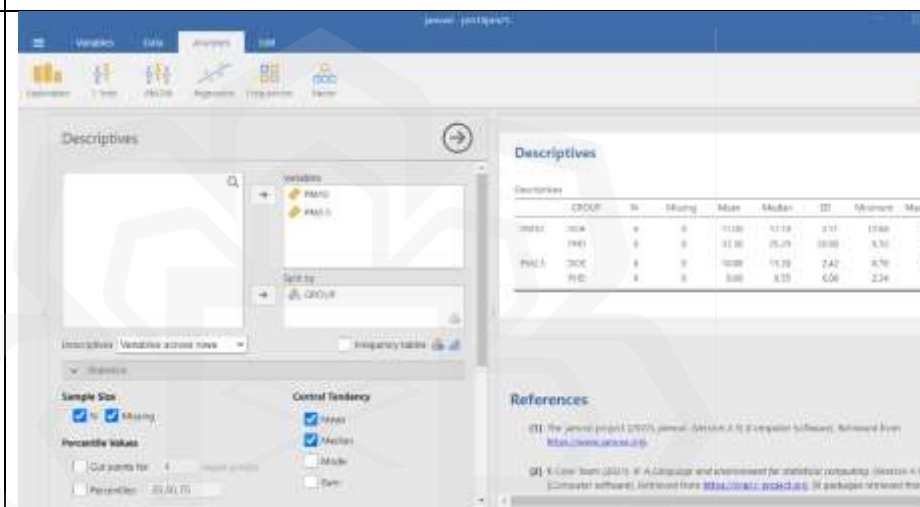
Blank sheet	
Create Data Variable for Independent	
Create Data Variable for Dependent Variable	

Entry of
data



	PM10	PM2.5
1	50.660	9.475
2	71.670	9.940
3	45.170	12.880
4	67.270	16.510
5	62.180	16.840
6	6.580	2.340
7	12.500	11.250
8	15.370	9.550
9	19.170	12.707
10	17.280	11.490
11	19.070	10.810
12	12.880	6.500

Performing
Descriptive
Analysis



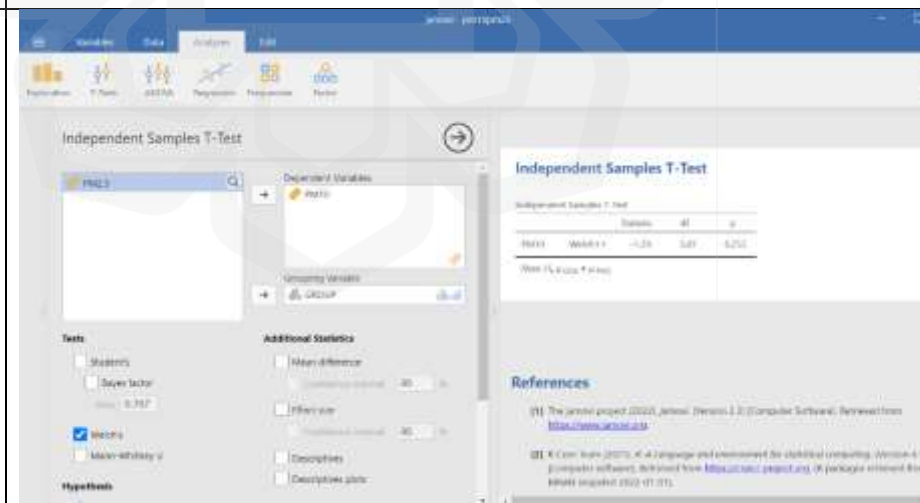
Descriptives

	GROUP	N	Missing	Mean	Median	SD	Minimum	Maximum
PM10	PM10	9	0	11.180	11.18	2.37	1.940	19.170
	PM2.5	9	0	11.86	15.29	10.98	5.70	16.840
PM2.5	PM2.5	9	0	10.98	11.29	2.42	6.500	12.880
	PM10	9	0	9.480	9.55	6.06	2.340	12.880

References

- [1] The jasp project (2020). jasp (Version 0.10) [Computer Software]. Retrieved from <https://www.jasp-stats.org/>
- [2] R Core Team (2019). R: A language and environment for statistical computing. (Version 4.1) [Computer software]. Retrieved from <https://www.R-project.org/> or package versioned from source (2020-07-01)

Performing
Independent
t-test for
PM2.5



Independent Samples T-Test

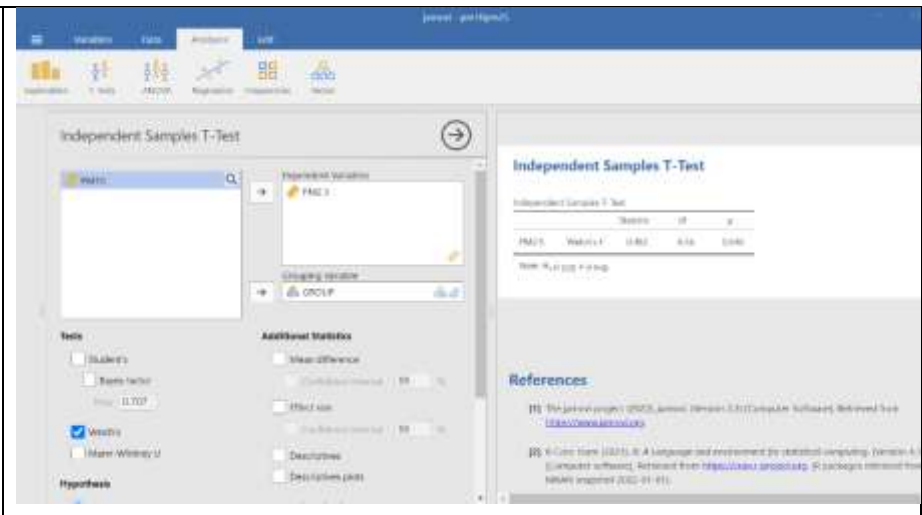
	Statistics	df	p	
PM2.5	Mean diff.	-0.29	5.87	6.250

With 1% significance level

References

- [1] The jasp project (2020). jasp (Version 0.10) [Computer Software]. Retrieved from <https://www.jasp-stats.org/>
- [2] R Core Team (2019). R: A language and environment for statistical computing. (Version 4.1) [Computer software]. Retrieved from <https://www.R-project.org/> or package versioned from source (2020-07-01)

Performing
Independent
t-test for
PM10



Independent Samples T-Test

Dependent variable: PM10
Independent variable: PM2.5

Test: ☐ Student's t-test
☐ Welch's t-test
☒ Welch's t-test (assumed equal variances)

Additional statistics: ☐ Mean difference
☐ Effect size
☐ Descriptives
☐ Descriptives plot

Hypothesis: ☐ Two-tailed
☐ One-tailed (greater)
☐ One-tailed (less)

Results

Statistic	df	p
T-Statistic	10	0.040

Note: Welch's t-test

References

- [1] The JASP project (2023). JASP: Statistical Software. Retrieved from <https://www.jasp-stats.org/>
- [2] R Core Team (2023). R: A language and environment for statistical computing. (Version 4.3.1) [Computer software]. Retrieved from <https://www.R-project.org/>. R packages retrieved from RStudio (version 2023.09.1).

