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RELATIONSHIP BETWEEN AIR QUALITY, METEOROLOGICAL FACTOR AND COVID-19 AT KUALA LUMPUR AND SELANGOR: AN ECOLOGICAL STUDY

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BY

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

ABSTRACT

RELATIONSHIP BETWEEN AIR QUALITY, METEOROLOGICAL FACTOR AND COVID-19 AT KUALA LUMPUR AND SELANGOR: AN ECOLOGICAL STUDY

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Introduction: Wuhan, People's Republic of China reported a coronavirus disease 19 (COVID-19) in December 2019 that cause by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). COVID-19 has become a global pandemic affecting many countries, including Malaysia. Here, the relationship between air quality, meteorological factors and COVID-19 cases in Kuala Lumpur and Selangor, Malaysia was determined. **Methodology:** Data on air pollutant levels (particulate matter ($PM_{2.5}$, PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3) and meteorological factors data included wind direction (WD), relative humidity (RH), ambient temperature (AT), wind speed (WS) and solar radiation (SR) obtained from 11 March to 1 June (2019-2020) was obtained from the Department of Environment Malaysia (DOE). Only Batu Muda Station and Petaling Jaya Station was included in our study. The daily and cumulative COVID-19 case numbers reported were retrieved from the Ministry of Health Malaysia (MOH). Spearman's correlation test was performed to study the association between air pollutant concentrations and meteorological with cumulative COVID-19 case numbers. To identify the most contributed variables that associated with COVID-19 cases, Multiple Linear Regression were performed. **Result:** Cumulative COVID-19 cases in Kuala Lumpur was greater than Selangor during this study period. Levels of several pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) indicated a sharp decline in 2020 early after the lockdown while level of O_3 increase. Spearman's correlation test shows cumulative COVID-19 cases have positive correlation in PM_{10}, $PM_{2.5}$, NO_2, O_3, and RH while negative correlation with WS and SR. The most significant air pollutant and meteorological factors with total cases of COVID-19 in the Kuala Lumpur are the RH ($r = 0.494$; $p<0.001$) and followed by $PM_{2.5}$ ($r=0.396$, $p<0.001$) in Selangor, while all other tests for other parameters failed. **Conclusion:** According to the findings, the air pollutant and meteorological factors have significant correlation with COVID-19 cases in Malaysia. In addition, the Malaysian government's efforts to restrict the spread of the COVID-19 pandemic have a major influence on air pollution levels in Malaysia. Furthermore, it is possible to argue that lower human outdoor activities, automobile emissions, and coal-fired power plant emissions all contribute to cleaner air.

Keyword: COVID-19, Air quality, Meteorological factors, Malaysia

ABSTRAK

HUBUNGAN ANTARA KUALITI UDARA, FAKTOR METEOROLOGI DAN COVID-19 DI KUALA LUMPUR DAN SELANGOR: KAJIAN EKOLOGI

NUR AFIZAN BINTI ABIDIN

Pendahuluan: Di Wuhan, Republik Rakyat China melaporkan penyakit coronavirus 19 (COVID-19) pada bulan Disember 2019 yang disebabkan oleh Sindrom Pernafasan Akut yang teruk Coronavirus 2 (SARS-CoV-2). COVID-19 telah menjadi wabak global yang melanda banyak negara, termasuk Malaysia. Di sini, hubungan antara kualiti udara, faktor meteorologi dan kes COVID-19 di Kuala Lumpur dan Selangor, Malaysia telah dikenal pasti. **Metodologi:** Data mengenai tahap pencemaran udara bahan zarah ($PM_{2.5}$, PM_{10}), nitrogen dioksida (NO_2), sulfur dioksida (SO_2), karbon monoksida (CO) dan ozon (O_3) serta data faktor meteorologi termasuk arah angin (WD) , kelembapan relatif (RH), suhu persekitaran (AT), kelajuan angin (WS) dan sinaran suria (SR) yang diperoleh dari 11 Mac hingga 1 Jun (2019-2020) diperoleh dari Jabatan Alam Sekitar Malaysia (JAS). Stesen Batu Muda dan Stesen Petaling Jaya termasuk dalam kajian kami. Nombor kes COVID-19 harian dan kumulatif yang dilaporkan diambil dari Kementerian Kesihatan Malaysia (KKM). Ujian korelasi Spearman digunakan untuk mengkaji hubungan antara kepekatan pencemaran udara dan meteorologi dengan nombor kes COVID-19 kumulatif. Untuk mengenal pasti pemboleh ubah yang paling banyak menyumbang yang berkaitan dengan kes COVID-19, Multiple Linear Regression dilakukan. **Hasil:** Kes kumulatif COVID-19 di Kuala Lumpur lebih besar daripada Selangor dalam tempoh kajian ini. Tahap beberapa pencemar (PM_{10}, $PM_{2.5}$, NO_2, SO_2 dan CO) menunjukkan penurunan mendadak pada tahun 2020 awal selepas kawalan pergerakan sementara tahap O_3 meningkat. Ujian korelasi Spearman menunjukkan kes COVID-19 kumulatif mempunyai korelasi positif pada PM_{10}, $PM_{2.5}$, NO_2, O_3 dan RH sementara korelasi negatif dengan WS dan SR. Faktor pencemaran udara dan meteorologi yang paling ketara dengan jumlah kes COVID-19 di Kuala Lumpur adalah RH ($r = 0.494$; $p <0.001$) dan diikuti oleh $PM_{2.5}$ ($r = 0.396$, $p <0.001$) di Selangor, sementara semua ujian lain untuk parameter lain gagal. **Kesimpulan:** Menurut hasil kajian, faktor pencemaran udara dan meteorologi mempunyai hubungan yang signifikan dengan kes COVID-19 di Malaysia. Di samping itu, usaha pemerintah Malaysia untuk menyekat penyebaran wabak COVID-19 mempunyai pengaruh besar terhadap tahap pencemaran udara di Malaysia. Lebih jauh lagi, ada kemungkinan untuk berpendapat bahawa aktiviti luaran manusia yang lebih rendah, pelepasan kenderaan, dan pelepasan loji kuasa arang batu semuanya menyumbang kepada udara yang lebih bersih.

Kata kunci: COVID-19, Kualiti udara, Faktor meteorologi, Malaysia

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LIST OF ABBREVIATIONS

COVID-19	Coronavirus diseases 2019
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
WHO	World Health Organization
CDC	Centre of Disease Control and Preventive
MOH	Ministry of Health
$PM_{2.5}$	Particulate matter with an aerodynamic diameter <2.5 µm
NOx	Particulate matter with an aerodynamic diameter <10.0 µm
CO	Carbon monoxide
SO_2	Sulphur Dioxide
O_3	Ozone
NO_2	Nitrogen dioxide
PM_{10}	Particulate Matter aerodynamic
MCO	Movement Control Order
CMCO	Conditional Movement Control Order
ACE2	Angiotensin-converting enzyme 2
SR	Solar Radiation
AT	Ambient Temperature
WS	Wind Speed
WD	Wind Direction
RH	Relative Humidity
SPSS	Statistical Package for the Social Science
p	Significant

r	Correlation
Ox	Photochemical Oxidant (Ox),
SPM	Suspended Particle Matter
T	Temperature
PSI	Pollutant Standards Index
NOx	Nitrogen oxide

CHAPTER 1

INTRODUCTION

1.1 Study Background

Since March 2020, the World Health Organization (WHO) reported the Coronavirus Disease 19 (COVID-19) as a global health emergency. COVID-19 is SARS-CoV-2 virus infectious disease initially reported in the city of Wuhan, China on December 2019 (WHO,2020). This virus is highly infectious and spreads rapidly to a lot of countries. Coronavirus disease (COVID-19) spreads internationally, affecting the world's economy and ecology in many different ways, not only as a health problem (Shakil et al., 2020). The SARS-CoV-2 has 4 major structural proteins that are spike glycoprotein (S), membrane (M), envelope (E) and nucleocapsid (N) (Fehr & Perlman, 2015). The spike of SARS-CoV-2 prevents neutralizing antibodies from reacting (Elengoe, 2020a).

From websites of Centers for Disease Control and Prevention (CDC), the principal mode is thru exposure to respiratory droplets that carrying infectious virus transmitted thru contact, droplet, and airborne. During exhalation (e.g., speaking, breathing, coughing, singing, sneezing) respiratory droplets already produce and can be classified into two main categories based on their ability to remain suspended in the air for an extended period of time based on their sizes. The smaller the size of the droplets, the longer time the droplets will remain in the air. Based on WHO, the respiratory infections are often transmitted through completely different sizes of droplets. The respiratory droplets have a diameter of < 5-10 μm while the droplet nuclei have a diameter of <5μm (WHO, 2020).

When a person comes into close contact (within 1 m) with someone who has respiratory symptoms, infectious respiratory droplets can form. If a person is in nearby to an infected person, transmission through fomites can occur (Ong et al., 2020). Airborne transmission different from droplet transmission in that it relates to the existence of microbes among the droplet nuclei, which are typically assumed to be <5μm diameter particles that can survive in the air for longer periods and be spread to others over distances more than 1 m. CDC mentions that the term "aerosol" has been utilized in varied ways in which to explain tiny particles which will move through the air. Based on previous studies, they conclude that SARS-CoV-2 aerosol is possible, as the virus will survive and contagious in aerosols long hours and on surface for days (Neeltje van Doremalen et al., 2020).

To prevent the transmission of the existing coronavirus, governments have placed limits on the movement of citizens and automobiles and suspended manufacturing operations. (Zambrano-Monserrate et al., 2020) . The government announce physical distancing and boundary closures to be a responsibility to control the disease. Most modes of transportation were outlawed, and almost all preventable human outdoor activity were halted throughout the country (Khomsi et al., 2021). As a result of those restrictions, greenhouse gas emissions, black carbon, nitrogen dioxide, and water contamination have all decreased dramatically (Shakil et al., 2020).

The extreme restriction on people movement resulted in a substantial decrease in pollutant concentrations, mostly attributed to vehicular traffic ($PM_{2.5}$, PM_{10}, NOx, CO, benzene, and BC) (Collivignarelli et al., 2020). During the lockout time, black carbon (BC) concentrations falling by 45–51 percent in Barcelona, Spain and air pollution levels fell by 50%, with nitrogen dioxide (Tobías et al., 2020a). However, during the lockout phase, the amount of ozone in Barcelona rise by 33% to 57 % (Tobías et al., 2020a). Carbon pollution in China declined by 25% during the lockout, amounting to about 1 million tonnes less than during the same time last year (Wang & Su, 2020). While, ($PM_{2.5}$) levels in Malaysia dropped by about 58.4% during the country's shutdown (Abdullah et al., 2020).

However, one of the most important indicators affecting COVID-19 distribution and death is air pollution (Abdullah et al., 2020). Study from Cui et al. (2003) study about Severe acute respiratory syndrome (SARS) have reported that individuals exposed to contaminated air had greater chance of infections and severity when compared to individuals identified in the least polluted areas.. Polluted air can cause several breathing problems in humans that making it easier for the virus to enter and attack them; on the other hand, NO_2 and $PM_{2.5}$, can cause the overexpression of ACE-2 in human respiratory cells, making it easier for the virus to attach to them (Paital & Agrawal, 2021). In addition, effect from chronic exposure of air pollution also can associated with the severity of COVID-19 infection.

1.2 Problem Statement

According to the World Health Organization (WHO), environmental contamination which is air pollution threatens an estimated seven million people worldwide per year. Ambient air quality was responsible for 4.2 million deaths globally in 2016. It is believed that indoor air contamination contributes to about 29 percent of lung cancer deaths, 24 %of stroke deaths, 25 %of heart attack deaths, and 43 percent of other lung diseases. Furthermore, air pollution exposure has been related to 26% of respiratory illness deaths, 25% of chronic obstructive pulmonary disease (COPD) deaths, and nearly 17% of ischemic heart disease and stroke. For COVID-19 outbreaks, people with chronic respiratory and cardiovascular disease have a substantially higher mortality risk. Several studies have shown a connection between low air quality and the frequency of COVID-19 outcomes (Li et al., 2020; Ogen, 2020; Wu et al., 2020; Zoran et al., 2020). These diseases are often closely related to air quality, suggesting that air pollution may be considered a secondary cause of these deaths (Isaifan, 2019).

The majority of air pollutants in the atmosphere have been contributed by traffic and industrial pollutants. Anthropogenic pollution levels are one of the world's most serious public health threats, stealing the lives of nearly 9 million people each year that have been stated by WHO. Long-term air pollution exposure is dangerous for reproductive, neurological and respiratory systems and could lead to cancer and even infrequently death (Manisalidis et al., 2020). It is important to note that the effects of dysfunction and neuroinflammation on the immune system (Genc et al., 2012), are associated with poor quality air. Increasing inflammation in more polluted areas could increase death and disease expression. People who live in polluted environments are more susceptible to SARS-CoV-2 infections and increased mortality, according to some research (Conticini et al., 2020; 2020; Zhu et al., 2020a). A study in China shows that the number of cumulative cases of COVID-19 in each area is positively associated with the Population Index, demonstrating the need for population control (Hu et al., 2020).

According to current data, the virus spreads mainly by respiratory droplets amongst individuals who are in close contact with one another. A study demonstrate that a certain amount of pathogens can be inhaled by others in the droppers created by talking, coughing, and sneezing, and that these pathogens can be passed from one person to the another via respiratory droplets (Yang et al., 2020). Aerosol transmission of coronavirus is possible since the virus will stay viable and contagious in aerosols for hours (Neeltje van Doremalen et al., 2020) and can travel across the air. Transmission may occur in unique environments where the infected person spends prolonged periods of time with others, especially in confined, crowded, and poorly ventilated spaces. According to the World Health Organization (WHO), certain medical procedures in health facilities, known as aerosol generating procedures, may create very tiny droplets (referred to as 'droplet nuclei' or 'aerosols') that may keep trapped in the air for long durations. This explains why health professionals conducting these operations take particular airborne safety precautions, such as wearing adequate personal protective devices, such as respirators, and why guests are not allowed in those regions.

SARS-COV-2 could attach to air particles, enabling them to stay in the air longer and penetrate the lungs, triggering serious respiratory effects, worsening health conditions, and sometimes contributing to death (Rabi et al., 2020). Individuals who are subjected to air pollutants on a daily basis are at a high risk of being contaminated with COVID-19 (Nasikhah & Pawitra, 2020). Variations in temperature and humidity have also been linked to influenza and other respiratory viruses like (SARS). In addition, difference in temperatures and humidity has been known to trigger virus especially respiratory viruses, including severe acute respiratory syndrome (SARS) (Tan et al., 2005). However, meteorological factors in each country and region are totally different and causal factor for each parameter may vary. Using these logics, a few research were conducted to investigate the impact of meteorological variables such as relative humidity, temperature, wind speed, dew point, and rainfall on COVID-19 spread. (Ma et al., 2020; Pani et al., 2020a; Sahoo et al., 2020; Wu et al., 2020).

1.3 Study Justification

This study aims to investigate about air quality, meteorological factor and COVID-19 works together. Then, to determine the trend of different air quality and meteorology factor levels, we also determine the trends of COVID-19. The data of air quality and meteorology factor control units were studied and compared to detect the correlation with COVID-19 cases. The previous study already recommends that air pollution and meteorology factor can act as risk factor to respiratory infection. So, association can be made to determine how air quality and meteorological factor can affect the COVID-19 infection.

The number cases of COVID-19 also will be observed cause by air changes. As we know the COVID-19 already changes our lifestyle and also our environment. The concern thing is air quality because we need oxygen every time. It will get into our lungs and enters the bloodstream when we breathe polluted air and is carried to our internal organs such as the brain. It may trigger severe health issues including asthma, cardiovascular disease, and even cancer, as well as a reduction in life quality and years.

Location of this study is selected due to the urbanization, industrial area and highly congested area that contribute to the air pollution and concern about people infected by the air pollution. From smog lingering over towns to smoke inside the building, air pollution is a major hazard to health and the environment. In combination with environmental (outdoor) and household air pollution, almost seven million premature deaths are recorded annually, attributed mainly to elevated stroke mortality, cardiac failure, chronic obstructive pulmonary disorder, lungs and acute respiratory disease.

Many researchers have determined that polluted air increased health risks associated with respiratory, cardiovascular, and other diseases, and has triggered wide attention in recent decades (Karimzadegan et al., 2008; Xing et al., 2016). Chronic diseases have been linked to environmental pollution, particularly in urban areas, according to scientific research. Monitoring pollutant concentrations such as SO_2 and NO_2 thus become critical, especially since many countries' pollution reduction initiatives are related to health risks.

To effectively control the transmission of COVID-19, it is crucial to determine the factors that influence SARS-CoV-2 transmission. From this study, we can determine the influence of air pollution exposure and variations in meteorological factors on COVID-19 transmission. This research can assist explain some of the variables that contributed to increased spread of COVID-19 in specific Malaysian locations, as well as guide policymakers in preventing future outbreaks like COVID-19.

1.4 Research Question

i. What are the trends of COVID-19 cases in Kuala Lumpur and Selangor?
ii. What is the air quality level during COVID-19 pandemic in Kuala Lumpur and Selangor, Malaysia?
iii. Are there any differences in air quality levels and meteorological data between 2019 and 2020?
iv. Are there any differences in air quality levels and meteorological data between before Movement Control Order (MCO) and during MCO?
v. Is there association between air quality, meteorological factors and COVID-19 cases in Kuala Lumpur and Selangor, Malaysia?

1.5 Research Objectives

<u>General Objective</u>

i. To determine the relationship between air quality, meteorological factors and COVID-19 cases in Kuala Lumpur and Selangor, Malaysia

<u>Specific Objective</u>

i. To determine the reported cases of COVID-19 at Kuala Lumpur and Selangor.
ii. To determine the daily data on level of air pollution and meteorological data at Batu Muda, Kuala Lumpur and Petaling Jaya, Selangor.

iii. To compare the level of air pollution and meteorological data on 2019 and 2020 in the same period of time.

iv. To compare the level of air quality and meteorological data before MCO and during MCO

v. To determine the association between air quality, meteorological factors, and COVID-19 cases in Kuala Lumpur and Selangor Malaysia.

vi. To determine the most significant factor associated with COVID-19 cases in Kuala Lumpur and Selangor

1.6 Research Hypothesis

i. There are significant differences between the level of air quality and meteorological before MCO and during MCO.

ii. There are significant differences between the level of air pollution and meteorological data in 2019 and 2020 in the same period of time.

iii. There are significant associations between air quality, meteorological factors, and COVID-19 cases in Kuala Lumpur and Selangor.

iv. There are significant associations between the most significant factor with COVID-19 cases in Batu Muda, Kuala Lumpur and Petaling Jaya, Selangor.

1.7. Definition

1.7.1 Conceptual Definition

i.) COVID-19 cases

WHO declared this epidemic outbreak in January 2020 as a novel coronavirus identified in 2019 (2019-nCoV) or SARS-CoV-2, and called the newly discovered coronavirus disease (COVID-19) in 2019 (World Health Organization, 2020)

ii.) Air Quality

Air quality is a measurement of how clean or polluted the air is. Air quality monitoring is necessary because contaminated air can be harmful to our health and the health of the ecosystem. The Air Quality Index (AQI) is used to describe air quality. Based on the concentration of pollutants in the air at a specific location.

iii.) Meteorological factor

Meteorological is of or pertaining to atmospheric phenomena, especially weather and weather conditions; "meteorological factors"; "meteorological chart"; "meteoric (or meteorological) phenomena"

1.7.2 Operational Definition

i.) COVID-19 cases

The COVID-19 cases in Malaysia can be obtained from the Ministry of Health, Malaysia (available at http://COVID-19.moh.gov.my/terkini). Only data in Kuala Lumpur and Selangor state were collected.

ii.) Air Quality

The air quality is obtained from the AQI parameters involved in measuring air quality are particulate matter with ≤ 10 µm diameter (PM_{10}), particulate matter with ≤ 2.5 µm diameter ($PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and carbon monoxide (CO). The Department of Environment Malaysia (DOE) provided the collected air quality from the air quality monitoring station. Only Batu Muda Station and Petaling Jaya Station were used in this study.

iii.) Meteorological factor

The meteorological data obtained from Department of Environment (DOE) included wind direction (WD), wind speed (WS), ambient temperature (AT), relative humidity (RH) and solar radiation (SR). Data collected from Batu Muda Station and Petaling Jaya Station was obtained from DOE.

CHAPTER 2:

LITERATURE REVIEW

2.1 COVID-19 cases

Coronavirus disease 2019 (COVID-19) is type of infectious disease that causes severe acute respiratory syndrome. It is caused by the newly discovered coronavirus 2 (SARS CoV-2) (WHO, 2020). A new outbreak of coronavirus disease 19 (COVID-19) was found in Wuhan, People's Republic of China, in December 2019. A new coronavirus, COVID-19, causes the disease by SARS-CoV-2 virus, which is believed to have spread to humans from other mammals and rapidly spreading global pandemic. World Health Organization (WHO) has taken an action to stop the disease transmission by implementing public health measures in almost every country.

This virus spreads quickly from person to person, but it spreads from animal to human through direct interaction with an intermediate host. The virus may also be transmitted by the ingestion of infected raw or semi-cooked meat. Asymptomatic people spread the infection through oral fluid droplets, primarily through airborne coughing or sneezing (Elengoe, 2020b). COVID-19 is a respiratory infection that causes cough, fever, and dyspnea, contributing to pneumonia (Jiang et al., 2020). Any affected patients can have mild symptoms including vomiting, muscle discomfort, sore throat, runny nose, or diarrhea, while some can develop serious pneumonia, acute respiratory tract infection, organ failure (e.g., kidney failure), and septic shock, which can contribute to death.

The new coronavirus, according to several studies, is an acute respiratory illness that can damage the lungs and respiratory systems (Chen et al., 2020; Gautam & Trivedi, 2020). Early research concluded that older age (Wu et al., 2020), a history of smoking (Liu et al., 2020), asthma, and cardiac failure are both contributing factors to the disease (Chen et al., 2020). Severe COVID-19 disease was linked to older age > 51 years of age, that underlying comorbidity such as chronic kidney disease and chronic pulmonary disease with the symptoms of fever, cough, diarrhea and shortness of breath (Sim et al., 2020).

On April 17, 2020, there were 2.2 million COVID-19 incidents registered globally, with 150,810 fatalities and 564,210 recovered cases As the cases expanded, several countries placed bans on transportation, commerce, and cultural events, as well as closing schools and colleges, cancelling exams, and imposing social distancing (Dantas et al., 2020).

2.1.1 COVID-19 transmission and mechanism

Direct transmission (cough, sneeze, and droplet inhalation transmission) and contact transmission are also typical ways to spread the current coronavirus (contact with nasal, dental, and eye mucous membranes) (Lu et al., 2020). COVID-19 is believed to spread similarly to SARS, which spread via contact, droplet, and airborne pathways (Yu et al., 2004). The other can inhale a particular quantity of viruses contained in droppers formed by talking, coughing, and sneezing and is spread through the air by respiratory droplets (Yang et al., 2020). Thus, the necessity of social isolation has been highlighted, and social networks have been included in the alerts, mainly the Ministry of Health (MOH), health care experts, and celebrities. On weekends and holidays, curfews have been enforced in regions with a large number of cases.

2.2 Air quality sources and effect

Since air is necessary for all living things to survive, it must be kept clean and secure. Due to the high concentration of many hazardous substances that are harmful to health, anthropogenic activities are a major source of air pollution in the environment (Gautam & Hens, 2020; Ghorani-Azam et al., 2016) The main sources of air pollution include economic development, power consumption, urbanization, transportation and motorization, as well as the rapid rise of the urbanization (Kaplan et al., 2019). Air pollution is caused by a variety of processes, including burning fossil fuels in automobiles (planes, trucks, cars, and other engines), power plants, factories, and home heating systems. This release of chemicals and harmful gases reacts with sunlight in ways that increase the substance's toxicity (Figure 2 1) (Usmani et al., 2020).

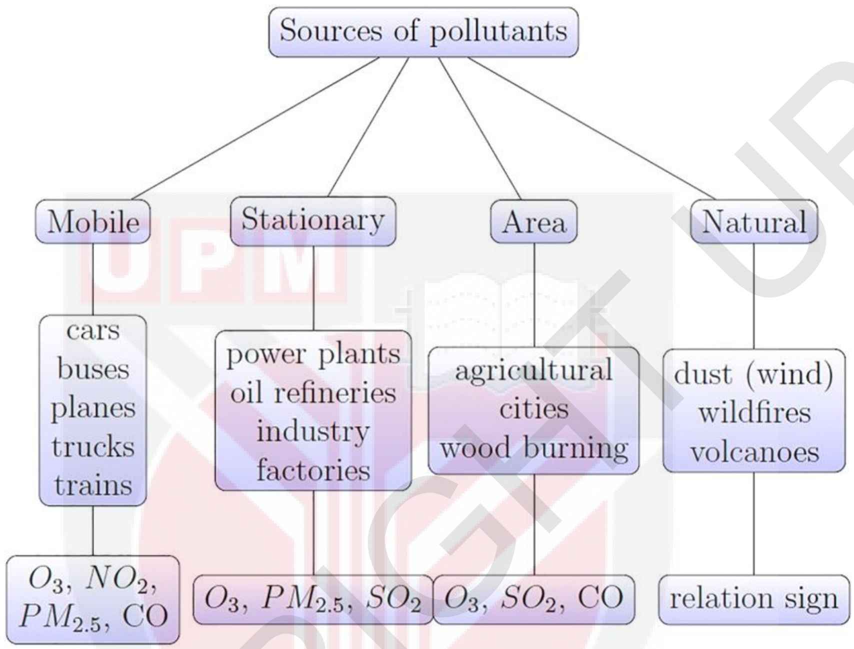

Figure 2.1. Sources of pollutants.

Particulate matter (PM), Carbon Monoxide (CO), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone (O_3) and carbon Dioxide (CO_2) are the major pollutants in our daily lives (Chen et al., 2007). NO_2 is a major component of urban air pollution since it is a precursor to ozone, particulates, and acid rain (Bechle et al., 2013). The largest source of NO_2 in the ambient environment is the combustion of fossil fuels such as oil, coal, and gas. NO_2 would be a highly reactive contaminant that is released, primarily from the combustion of fossil fuels. Transportation is thought to be the main source of NO_2 emissions (Muhammad et al., 2020).

It is well established that when economic growth declines, so does air quality. Industries have been shut down, vehicular flow has been halted, and people's everyday lives have been affected. As a consequence, major changes in air quality have been recorded in countries like Spain (Tobías et al., 2020a), India (Gautam, 2020), Brazil (Nakada & Urban, 2020), and China (Sharma et al., 2020a).

Most nations, like Malaysia, conduct air quality control dependent on a variety of atmospheric contaminants (Baldasano et al., 2003). These studies are important if air quality management activities are to be conducted, long-term air pollution changes are to be monitored, potential sources are to be identified and detected, and the efficacy of air pollution control regulations is to be improved (Özden et al., 2008). The main air pollutants recorded at Malaysia's monitoring stations are particulate matter (PM_{10} and $PM_{2.5}$), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), and Ozone (O_3), which are consistent with findings in most other countries (Awang et al., 2000).

2.2.1 Health impact on air quality

Prolonged exposure to air pollution has been associated to asthma attacks, acute respiratory inflammation, and death from cardiorespiratory disorders in previous research (Dockery & Pope, 1994; Schwartz et al., 1993; Schwartz & Dockery, 1992). $PM_{2.5}$, was being considered to be one of the most dangerous environmental health risks, causing millions of deaths each year throughout the world. (Lelieveld et al., 2015; Jos Lelieveld et al., 2019).

The study from Willers et al. (2013) reported that sensitivity to PM from car exhaust increases the likelihood of respiratory health problems in urban residents. They discovered that sensitivity to PM from car exhaust might raise the risk of respiratory health symptoms in urban residents. Fine particulate matter ($PM_{2.5}$) is definitely related to mortality and cardiovascular events, likely because it can reach deep into the lungs and trigger systemic inflammation (Willers et al., 2013).

2.2.2 COVID-19 and health effect from long-term exposure to air pollution

The findings of a study shows that long-term exposure to air pollutants makes people more vulnerable to the occurrence of more serious COVID-19 effects (Comunian et al., 2020). Lung inflammation is caused by chronic NO_2 pollution toxicity. This disorder will trigger a decline in body immunity, which will expose you to infectious diseases (COVID-19) (Ogen, 2020). In the most contaminated regions, an increase in inflammation could raise the fatality rate and the severity of disease expression. The virus binds to the angiotensin-converting enzyme 2 (ACE2) receptor in way to open the cell; ACE2 generates an anti-inflammatory peptide that is overexpressed in conditions of inflammation, such as from PM exposure, increasing the chances of COVID-19 entering the cells (Lin et al., 2018). The prevalence of ambient air contamination, especially PM_{10}, $PM_{2.5}$, and O_3, may impair the body's immunity over time. This can result in an increase in ACE2 development, leading to an increase in COVID-19 infection (Nasikhah & Pawitra, 2020). The incidence of COVID-19 infection would increase in the population of smokers and people having chronic obstructive pulmonary disease (COPD). The condition is most likely caused by an increase in the ACE2 receptor, which serves as the SARS-CoV-2 entry receptor (Tsatsakis et al., 2020).

Figure 2 study from (Ni et al. 2020) illustrates a model for the SARS-CoV-2 mechanism that enters the lung's host cells and attacks other organ in the body. When spike glycoprotein of SARS-CoV-2 reaches the lungs, where it binds to ACE2 on cells, it will be enabling the virus to enter the cells. The cell-free and macrophage phagocytosis-associated with virus can migrate from the lungs into other high-ACE2 organ circulation through blood circulation.

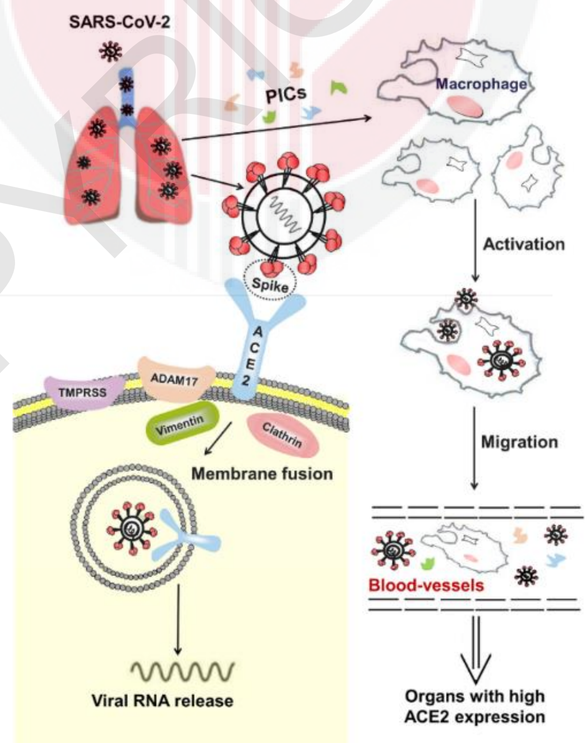

Figure 2.2 SARS-CoV-2 virus entering the lung

2.3 COVID-19 and air pollution

It should be concluded at this point that those with cardiovascular disease and chronic respiratory disease had a much higher COVID-19 death rate (Huang et al., 2020). These diseases are also well associated with air pollution, implying that air pollution could be considered a secondary factor for these mortality rates. Previous research has established the link between air pollution and the occurrence of a variety of health issues (Isaifan, 2019). These viruses can attach to air particles, allowing them to stay in the air longer and reach the lungs, resulting in severe respiratory symptoms, deteriorating health impacts, and even death (Rabi et al., 2020). In the case of COVID-19 airborne transmission, by World Health Organization (WHO) initially stated that the virus would stay in the air for two hours in a closed environment.

The infection risk with some airborne viruses has been demonstrated to rise with the presence of fine particles that could persist in the air for long durations, travel large distances, and penetrate deep into the lungs. Aerosol may play a role in indirect systemic effects in the body system, such as pro-inflammatory and oxidative mechanisms in the lungs and extrapulmonary organs, as well as immunological modification processes (Contini & Costabile, 2020). Although confounding factors (including the age and gender of individuals exposed) may exist, it is fair to believe that air pollution has a negative effect on COVID-19 patients' prognosis (Contini & Costabile, 2020).

An ecological study of the recent SARS in China was reported in a study (Cui et al., 2003) and found Patients were more likely to die in areas with moderate concentrations of pollutants (air pollution index, API) than in areas with low APIs. Air pollution could make COVID-19 patients more vulnerable and have a negative impact on their prognosis. Many studies have shown that exposure to prolonged air pollution, in example nitrogen dioxide (NO_2) which a toxic component, can also cause the incidence of these diseases (Ogen, 2020). Air pollution has been linked to COVID-19 deaths and cases in England, adding to previous results associating Europe's high mortality rates to increased hazardous exposure to air pollutants (Conticini et al., 2020; Ogen, 2020).

Prolonged exposures to pollutants in the air also triggers a chronic inflammatory response and raises the risk of infection by viruses that attack the respiratory system (Conticini et al., 2020; Selley et al., 2020). Moreover, the viability of SARS-CoV-2 recently been shown to increase airborne particulate matter (PM), indicates direct airborne pathogenic transmission and increased likelihood of infection in highly polluted regions (Setti et al., 2020). A number of studies have been conducted around the world to look into the link between poor air quality and the severity of COVID-19. According to some study, people who live in polluted surroundings are more susceptible to SARS-CoV-2 infections and have a higher fatality rate because they are more likely to have chronic respiratory difficulties (Conticini et al., 2020; Pansini & Fornacca, 2020; Zhu et al., 2020a).

Figure 2.4 study from Paital & Agrawal, (2021) shows how chronic exposure of air pollutant can causes respiratory symptoms and lead to COVID-19 infection. The susceptibility to disease for example in COVID-19 disease can increase by air pollution exposure. COVID-19 patients may express their severity into several category such as asymptomatic, mild symptomatic and severely symptomatic based on expression level of Angiotensin Converting Enzyme 2 (ACE-2) in alveolar cells of lungs as low (↑), moderate (↑↑) and high (↑↑↑), depending upon the level of NO_2, $PM_{2.5}$ level and NOX. Exposure of these air pollution may contribute with low host defenses, high susceptibility to disease and induced with low host of immunity that may causes high viral load of SAR-CoV-2 virus and increase the severity of COVID-19 disease that may lead to death.

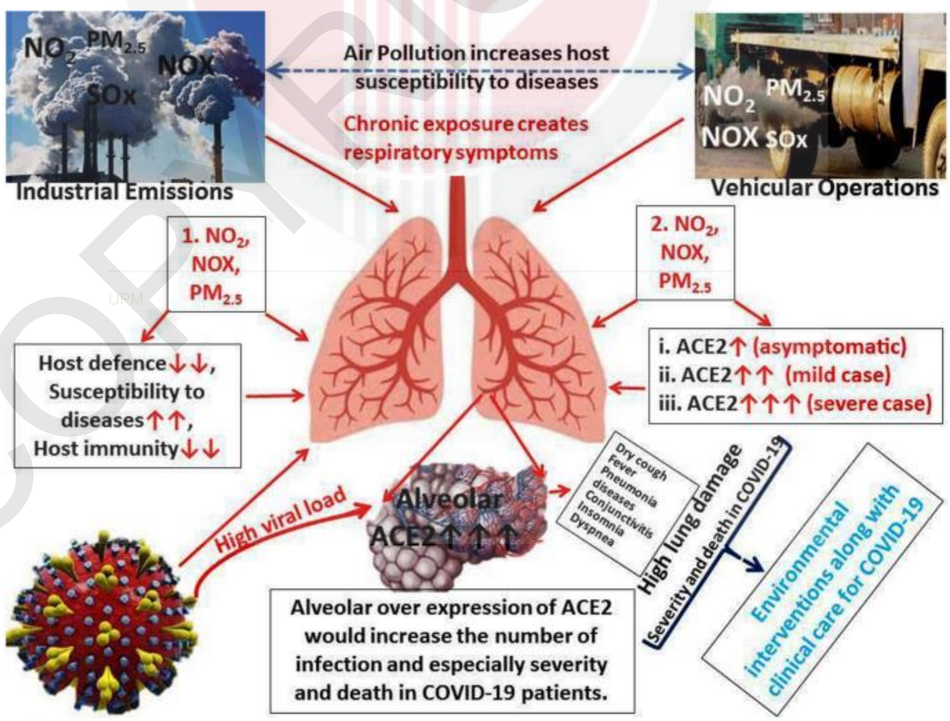

Figure 2.4. Effect of chronic exposure of air pollution in human body

2.4 COVID-19 and meteorological factor

These meteorological factors parameter, such as humidity, visibility, and wind speed, can influence droplet stability in the environment, as well as virus survival, as air temperature does, and thus effect epidemic spread (Chen et al., 2020). According to some studies, climate change may have enhanced in the emergence and spread of various infectious diseases (Gale et al., 2010; Lofgren et al., 2007) , including the SARS and COVID-19.

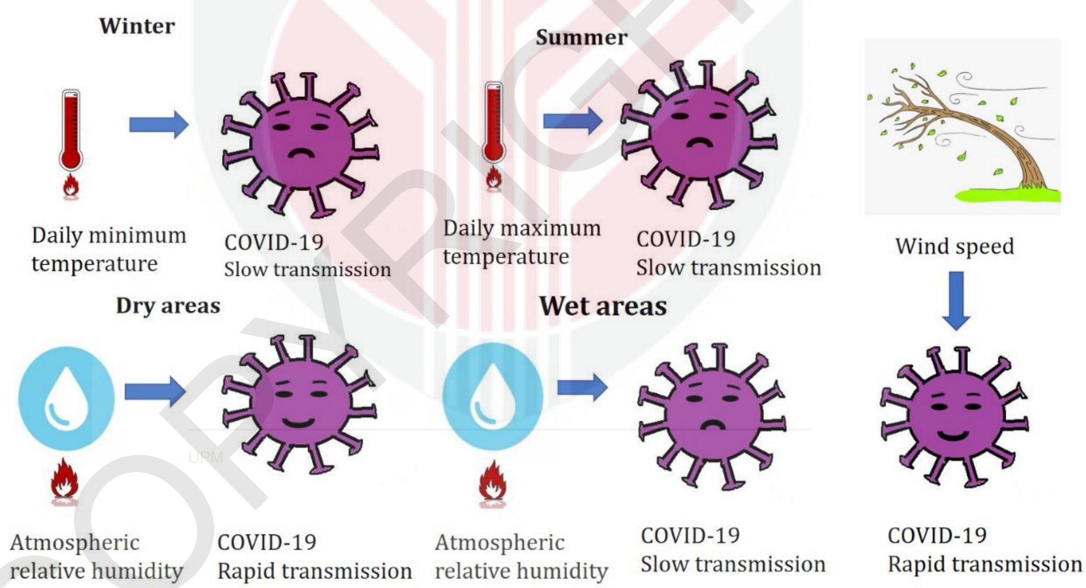

Figure 2.5 Relationship between season and condition with COVID-19 transmission

The main driving factors for the COVID-19 transmission were temperature and relative humidity, but their relationship with the season and geography clearly varied. Figure 2.5 shows the mechanism of meteorological factor with COVID-19 transmission

(Yang et al., 2021) In the summer, higher relative humidity and a drop in maximum temperature promote COVID-19 transmission in arid inland towns, while a drop in relative humidity is beneficial for COVID-19 growth in coastal cities. In humid cities, the fall in relative humidity and minimum temperature in the winter enhance COVID-19 transmission.

Researchers suggested that PM might act as a droplet carrier via airborne transmission, triggering transmission of the virus (Setti et al., 2020). Once airborne, tiny particles carrying viruses can survive for a long period in the air, allowing for spread to other places (Pan et al., 2019). In low temperatures and high humidity conditions, droplets go farther, while aerosol particles increase in high temperatures and low humidity conditions. (Zhao et al., 2020). Droplets may travel as far as 6 m in extreme cold and humid environment (Zhao et al., 2020). Several studies on COVID-19 and meteorological factors have concluded that lower and higher temperatures may be beneficial in lowering COVID-19 infection rate (Shi et al., 2020). Other researchers claim that temperature has a significant relationship with the number of COVID-19 cases (Tosepu et al., 2020)

2.5 Air quality, meteorological factor and COVID 19.

Table 2.1. summary of finding relationship between air quality, meteorological factors and COVID-19.

Authors	Country/Area	Study variables	Findings
(Bashir et al., 2020)	California state, USA	- $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, Pb, VOC and COVID-19 cases.	$PM_{2.5}$, PM_{10}, SO_2, NO_2, and CO had a significant correlation with the COVID- 19 cases
(Saha et al., n.d.)	Cities of India	- PM $_{2.5}$ AQI, PM_{10} AQI, NO_2 AQI, SO_2 AQI, CO AQI, O_3 AQI, and overall AQI - COVID–19 variables: total confirmed, active, and deceased cases	Have significant correlation between COVID-19 deaths with poor air quality
(Huang et al., 2020)	China,	- $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO and O_3 - average temperature, wind speed, relative humidity, and precipitation. - COVID-19 cases: total cases, recovered cases and deaths	The average temperature and AQI showed significant association with the mortality rate of COVID-19.
(Lin et al., 2020)	China, Hong Kong, and Singapore	- RH, T, Confirmed COVID-19 cases	Temperature and relative humidity correlation can enhance COVID-19 transmission

(Islam et al., 2021)	Bangladesh	- $PM_{2.5}$, O_3, NO_2, SO_2 and CO - Temperature, pressure, relative humidity, and wind speed - Daily COVID-19 cases data	The daily COVID-19 cases had significantly correlated with pressure (lag-14 days) and relative humidity (lag-0 days)
(Bolaño-Ortiz et al., 2020)	Latin America and the Caribbean region	- Air pollution and climatic patterns: rainfall, average RH, WS, and urban air quality ($PM_{2.5}$, PM_{10}, and NO_2) - COVID-19 variables: daily new cases, total cases and deaths.	For various cities, humidity, rainfall, and wind speed demonstrated a significant association with daily cases, total cases, and death.
(Kolluru et al., 2021)	India	- AQI, PM_{10}, $PM_{2.5}$, CO and O_3, T, RH and WS, COVID-19 confirmed and deaths cases	During the lockdown, PM_{10}, $PM_{2.5}$, CO, O_3, AQI and meteorological parameters had a significant association with confirmed cases and deaths.
(Travaglio et al., 2020)	England	- NO_2, NO and O_3 - cumulative number of COVID-19 cases and deaths	COVID-19 cases are significantly predicted by nitrogen oxide and nitrogen dioxide levels ($p < 0.05$).
(Pirouz et al., 2020)	Italy	- Daily average temperature, relative humidity, and wind speed, - total confirmed COVID-19 cases	The impacts of parameters have been considered with a delay time from one to nine days to find out the most suitable combination

Table 1 represent the finding of several study in various country that have been conducted to examine the link between air pollution, meteorological factors and COVID-19. It can be summarized that, air pollutant parameter has significant correlation with COVID-19 cases, same as meteorological factors parameters. There are vary COVID-19 variables that can be study which is daily cases, confirmed cases and also deaths cases of COVID-19.

Study in California (Bashir et al., 2020), India (Kolluru et al., 2021), and Italy (Travaglio et al., 2020) have been reported significant relationship between of air pollution parameters with COVID-19 cases. While, study of meteorological parameter were conducted by (Bolaño-Ortiz et al., 2020; Huang et al., 2020; Islam et al., 2021; Lin et al., 2020) shows significant association with COVID-19 cases. There are also have several study that shows both parameters which is air pollutant and meteorological factor that had significant correlation with COVID-19 cases (Huang et al., 2020; Kolluru et al., 2021). Overall, air pollutant parameters ($PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, CO, AQI) and meteorological factors variables such as humidity, rainfall, pressure, wind speed, temperature and relative humidity have significant association with COVID-19 variables such as daily cases, total cases and death cases.

Study from Travaglio et al. (2020) shows significant predictors for COVID-19 infectious are the nitrogen dioxide and nitrogen oxide. They used negative binomial regression model in their study to predicted the correlation between COVID-19 cumulative cases and death with air pollutant. To study the long-term effect of air pollution with COVID-19, data of air pollutants for 2018 and 2019 were collected due to no COVID-19 cases were identified. While study for meteorological factors or climate changes with COVID-19 cases also have been studied by a few researchers. Study in Italy to examined the climate factors (daily average temperature, wind speed and relative humidity) affected on the COVID-19 cases (total confirmed COVID-19 cases) were analyses by using Mathematical Modeling and Multivariate Linear Regression Analysis. The finding of the study has been proved that impact of the parameters that can affect the COVID-19 infection could be considered with one to nine days delay of time to find out the correlation.

CHAPTER 3:

METHODOLOGY

3.1 Study Design

The study design used is an ecological study. For these ecological studies, the population or community of Kuala Lumpur and Selangor is the unit of observation. COVID-19 cases and exposure to air pollution and meteorological factors are measured in populations and their relation will be determined. The information about disease and exposure is abstracted from published statistics which is from DOE and MOH. Ecological studies are conducted because it difficult or impossible to obtain data at individual levels. Therefore, ecological studies have been performed to correlates population rates of the COVID-19 diseases with interest factors which is air pollution and meteorological factor.

3.2 Study Location

The region of Kuala Lumpur is located from 3°8′52″N to 101°41′43″E. The capital city of Malaysia has an area of 243 km^2 and has the largest population density of 7328 people km^2. Selangor was selected as the study location because it is Malaysia's most populous state, with 5.46 million people, as well as having a high degree of urban development (91.4 %). Monitoring station located at both area are at Sekolah Kebangsaan Batu Muda, Kuala Lumpur and Sri Petaling Primary School, Petaling Jaya; Selangor. The air monitoring station of Petaling Jaya (N03° 06.612', E101° 42.274'; S1) is located in Sri Petaling Primary School, Petaling Jaya; Selangor. The sampling station is close to Kuala Lumpur's metropolitan region, and it is accompanied by industry, residential, and commercial areas, resulting in congested highways.

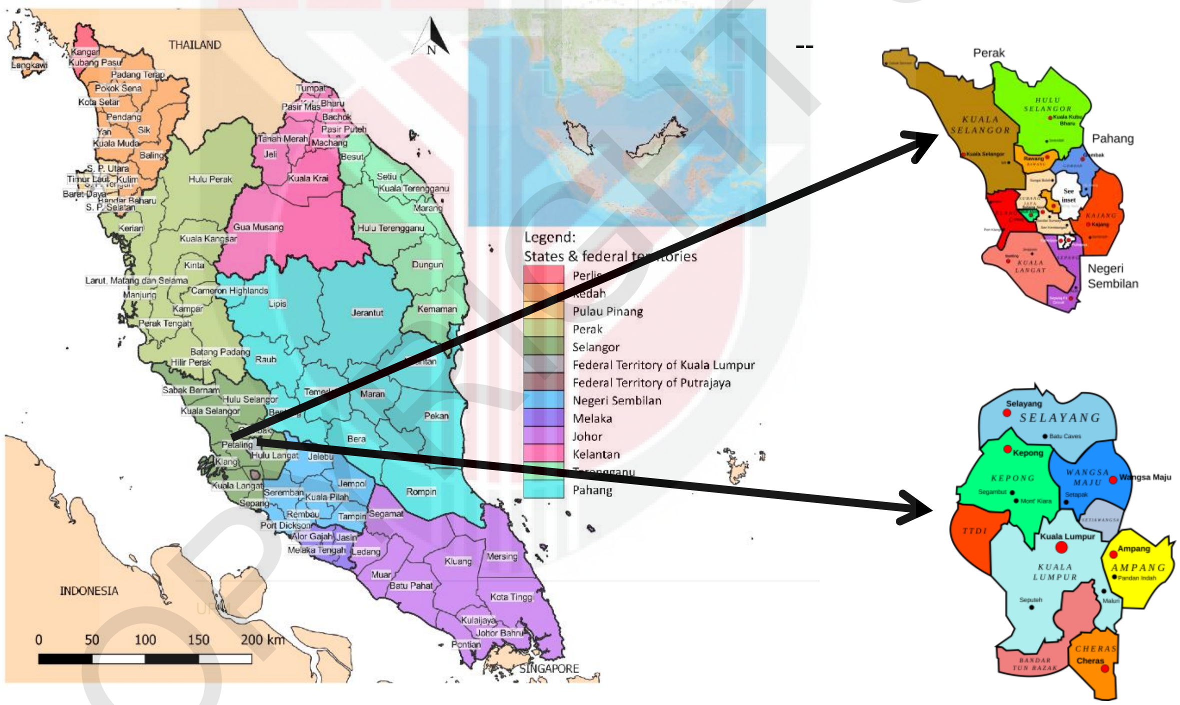

Figure 3.1. Mapping of Kuala Lumpur and Selangor, Malaysia

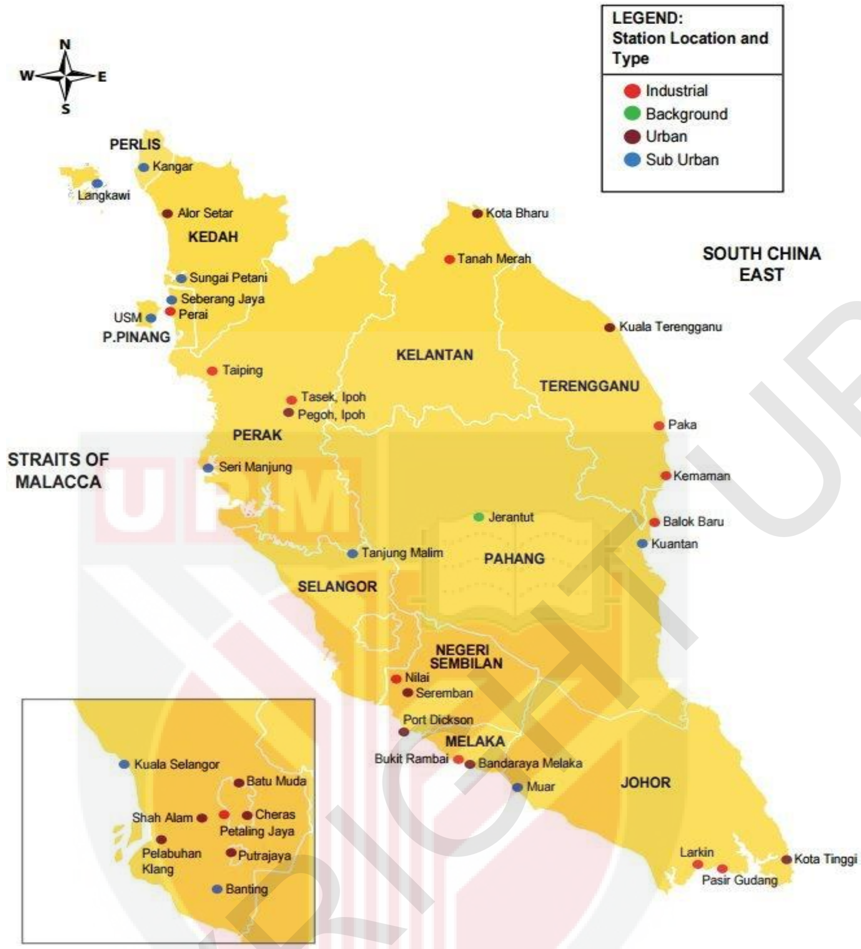

Figure 3.2. Location of Batu Muda Station and Petaling Jaya Station

3.3. Study Method

3.3.1 Study Strategy

Data of air quality, meteorological data and COVID-19 cases are gathered from various public authorities. The Department of Environment Malaysia provided air quality and meteorological data collected at an air quality monitoring station. The study area is known as a highly congested area, high population and surrounded by industrial, residential and congested road. COVID-19 cases reported in both areas are high.

3.3.2 Duration Frame

The time of the study observe is twelve weeks which started from 4 March 2020 until 26 May 2020 to study the relationship between air quality, meteorological factors and COVID-19 cases. To study the trends of COVID-19 cases, the duration is 18 March 2020 until 26 May 2020.

Next, compared air pollutant and meteorological data between 2019 and 2020 the duration from 4 March 2019- 26 May 2019 and 4 May 2020 until 26 May 2020 respectively. Also compared air pollutant and meteorological data between before MCO and during MCO which is 4 March 2020 until 17 March 2020 between 18 March 2020 until 26 May 2020, respectively.

While, to determine the prolonged exposure to air pollutants and differences concentrations of air pollutants, the data collected in 2019, when no COVID-19 case were reported with referred from a study from (Travaglio et al., 2020). The selected date is from 11 March until 26 May for 2019. To determine the direct relationship of meteorological factors with COVID-19 infection, the data were observed in 2020. The impact of meteorological parameters could last for a few days (Elengoe, 2020a), and COVID-19 has 1 to 14 days incubation period (CDC, 2020). Assuming that the usual duration from virus transmission to infection is seven days, the average daily air quality and meteorological parameters of seven days ago have been compared with total reported cases of MCO day. Example of correlation, COVID-19 new case on 18 March 2020 against average air quality on 11 March 2019 and meteorology parameters on 11 March 2020.

3.4 Data Collection

The air pollutants and meteorological was gained from the Department of Environment (DOE) under the Ministry of Environment and Water, Malaysia, at Batu Muda Station, Kuala Lumpur and Petaling Jaya Station, Selangor. Only wind speed (WS), wind direction (WD), solar radiation (SR), relative humidity (RH) and ambient temperature (AT), data for meteorological factors include, while for air pollutants data consists of particulate matter with ≤ 2.5 µm diameter ($PM_{2.5}$), particulate matter with ≤ 10 µm diameter (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO). While, the data on COVID-19 infections in Malaysia was collected from the Malaysian Ministry of Health. (available at http://COVID-19.moh.gov.my/terkini).

3.6 Data Analysis

The statistical analysis was carried out using SPSS Version 25. To analyses a statistically significant difference within two related sample means for data that were normally distributed the paired-samples t-test have been performed. The Wilcoxon signed-rank test was conducted to analyses a non-normally distributed paired sample. As the data not normally distributed, the Spearman rank correlation test was used in this study to examine the correlation at bivariate level between the air quality variables, meteorological factors, and the cumulative number of COVID-19 cases. Air pollutant data on 2019 were correlate with cumulative COVID-19 cases data to determine the long-term effect of air pollutant while for meteorological factors data in 2020 were correlate with cumulative COVID-19 cases. A multivariate level was examined by a multiple linear regression at bivariate levels were statistically significant determine the association between COVID-19 cases and the most contributed factors in multivariate analysis.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Status of the COVID-19 outbreak situation in Malaysia

Figure 1 shows the trends of active COVID-19 cases reported in Kuala Lumpur and Selangor on MCO Day, with 119 and 192 cases recorded, respectively. At the beginning of the study, Selangor state was having highest number of cases compared to Kuala Lumpur state. As of 1 Jun 2020, a total of 7,857 COVID-19 cases had been reported in Malaysia (MOH, 2020). The state of Kuala Lumpur had the highest cases, with 2,039, 1,920 of which were in the state of Selangor.

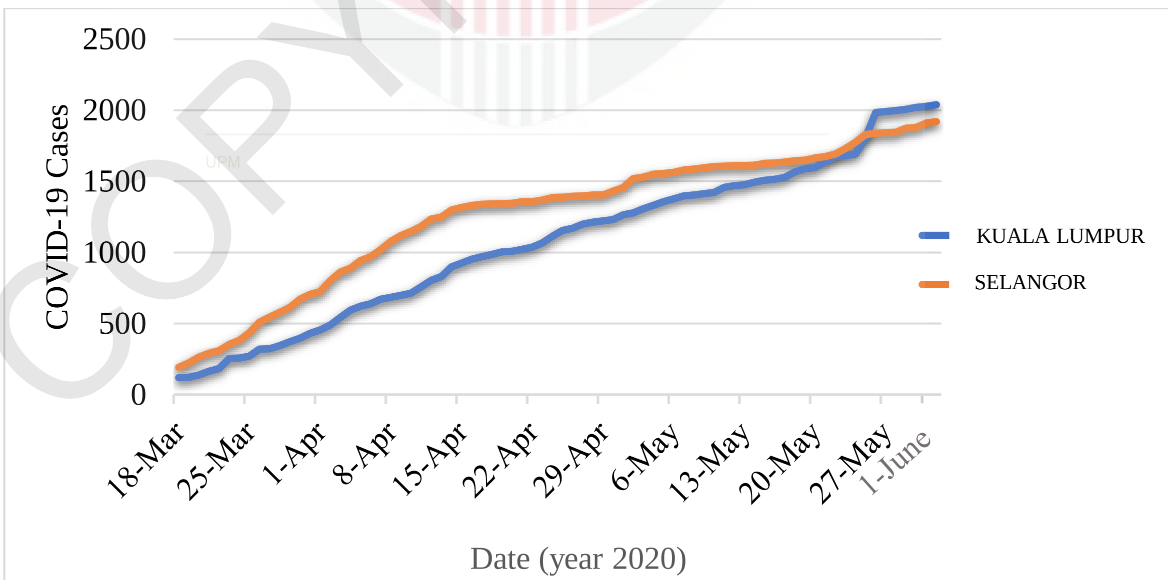

Figure 4.1. Cumulative COVID-19 cases in Kuala Lumpur and Selangor from 18 March to 1 June 2020

Figure 2 shows the daily COVID-19 cases in Kuala Lumpur and Selangor. The highest number of cases in Kuala Lumpur is 177 cases on 26 May 2020 while for Selangor is 75 cases on 26 March 2020. While the lowest number of cases is one for both states. We can see that from the figure, the cases in Kuala Lumpur increase drastically from 24 May to 26 May and drop to 5 cases on 27 May. From the increasing cases on that day, the cumulative cases in Kuala Lumpur become greater than cumulative cases in Selangor that make Kuala Lumpur state the highest number of total COVID-19 cases in Malaysia.

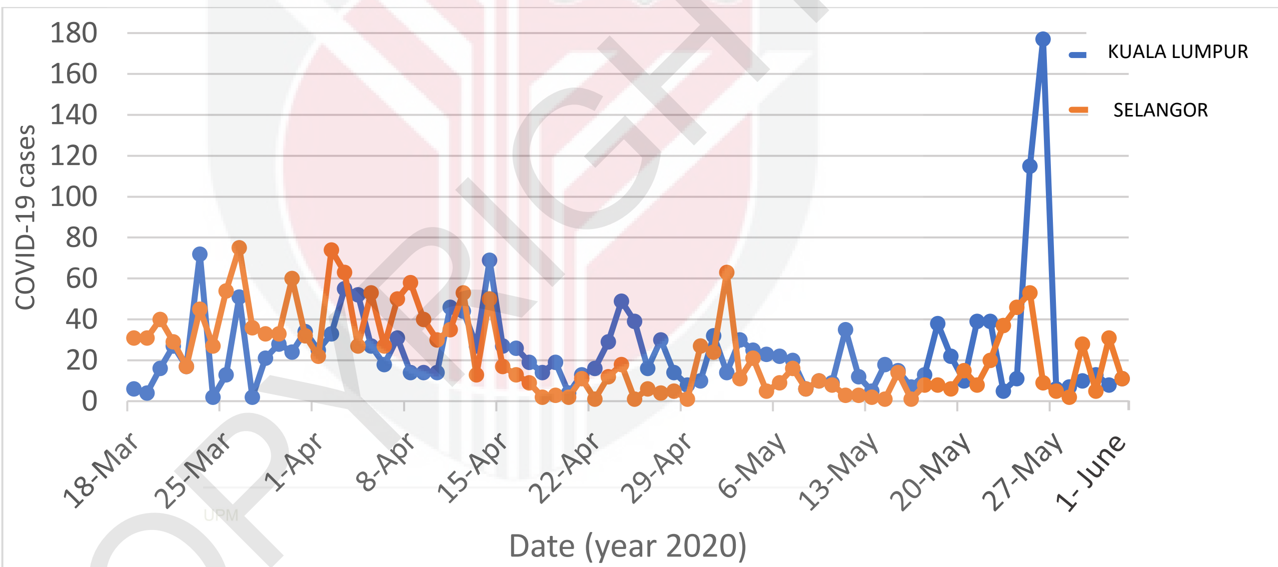

Figure 4.2. Daily COVID-19 cases in Kuala Lumpur and Selangor from 18 March to 1 June 2020

115 deaths were reported in Malaysia caused to COVID-19 infection throughout the study period (18 March 2020 to 1 June 2020). Finding from a study from Suhaimi et al., (2020), stated that the majority of deaths occurred in patients with chronic diseases;

that have at least two chronic diseases. Diabetes, heart disease, stroke, asthma, stroke, kidney disease, and dementia were all examples of chronic diseases. High levels of air pollution, particularly in cities, can lead to a variety of health issue, including cardiovascular disease, respiratory disease, and heart disease, especially in the urban areas. It also has become one of the causal factors of COVID-19 infection. Air pollution also can enhance the likelihood of COVID-19 infection by comorbidities or by other respiratory illness (Dutheil et al., 2020). When a person has comorbid diseases, their immune system may be impaired, or they may require extra care that risks them to others. Furthermore, individuals may already be having issues as a result of the underlying disease, which places further stress on their bodies (Gillespie, 2021).

Cilia and upper airways defences could have been weakened by persistent exposure to air pollution, which may have encouraged viral invasion by allowing viruses to invade lower airways and increase COVID-19 occurrence and lethality (Conticini et al., 2020). The increased incidence and lethality of a virus, highly infectious viral agent like SARS-CoV-2, especially among a population living in areas with greater levels of air pollution. In the study of the correlation between air pollution and COVID-19 infection, Zhu et al. (2020) had found that the relationship between air pollution and COVID-19 infection is statistically significant while, Liu et al. (2020) studied the relationship between COVID-19 cases and meteorological factors, where results indicated that mild diurnal temperature ranges, low humidity and low temperatures could favor COVID-19 spreading.

4.2 Concentrations of air pollutants and meteorological parameters before and during MCO

Many processes cause air pollution in automotive (aircraft, trucks, automobiles, and other engines) and power plants, industries, and household heating systems. This release of chemicals and harmful gases interacts with sunlight in ways that increase the toxicity of the material (Usmani et al., 2020). As predicted, the lockdown, which included restricted social interaction, the closure of restaurants, stores, and a huge number of companies and administrative centres, temporarily reduced levels of particular air contaminants, primarily those controlled by primary sources. Severals study also reported significant reduction of air pollution and improved of air quality in their region during lockdown (Abdullah et al., 2020; Muhammad et al., 2020; Wang & Su, 2020; Zambrano-Monserrate et al., 2020).

Table 4.1 and Table 4.2 presents the minimum, maximum, mean, standard deviation, median, interquartile range values, of the daily air pollutants and the meteorological factors from March 18 to June 1, 2019, as well as the same time frame in 2020 for Kuala Lumpur and Selangor respectively. This 11-week period represents MCO in Malaysia, with MCO start on March 18, 2020. The mean concentration of normally distributed

Table 4.1 shows O_3 was compared between these two years using a paired-samples t-test (effect size, *d*) while others parameters (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, WD, WS, RH, AT, and SR) were using a Wilcoxon signed-rank test (effect size, *r*). On average, in 2020, all air quality parameters showed lower concentrations than in 2019 except for parameter $PM_{2.5}$. Average of $PM_{2.5}$ in 2020 is higher 0.22 µg/m^3 from 2019. These differences were statistically significant (t or Z) at $p < 0.05$, showing MCO's efficacy in reduced contaminated air levels. NO_2 had a large effect size ($d \geq 0.80$ or $r \geq 0.80$)), while SO_2 and CO had a medium effect size ($r \geq 0.50$). However, excluding AT, all meteorological variables had statistically significant differences (t or Z) at $p < 0.05$. SR had highest effect size compared to others variables which is 0.68 as medium effect sized ($r \geq 0.50$).

Table 4.2 shows that NO_2, CO, and O_3 was compared between these two years using a paired-samples t-test (effect size, *d*) while other parameters (PM_{10}, $PM_{2.5}$, SO_2, WD, WS, RH, AT, and SR) were using a Wilcoxon signed-rank test (effect size, *r*). On average, in 2020, all air quality parameters showed lower concentrations than in 2019. These differences were statistically significant (t or Z) at $p < 0.05$, showing MCO's efficacy in reduced contaminated air levels. NO_2, CO and O_3 had a large effect size ($d \geq 0.80$ or $r \geq 0.80$), while $PM_{2.5}$ an PM_{10} had a medium effect size ($r \geq 0.50$). However, excluding SR, all meteorological factors variables had no statistically significant differences (t or Z) at $p < 0.05$. SR had highest effect size compared to others variables which is 0.70 as medium effect sized ($r \geq 0.50$).

Table 4.1. Descriptive statistics and differences analysis of air pollutants and meteorological data in Kuala Lumpur

Variables	Year	Min	Max	Mean	SD	Median	IQR	t or Z	p	d or r
PM_{10} (μg/m^3) [b]	2019	24.38	100.1	52.05	14.89	50.23	18.55	-2.449	**0.014***	0.28
	2020	18.93	94.06	44.69	15.67	41.73	22.74			
$PM_{2.5}$ (μg/m^3) [b]	2019	16.91	75.69	39.80	12.23	38.29	15.90	-1.558	0.119	0.18
	2020	15.45	309.1	40.02	34.26	35.33	16.81			
SO_2 (ppb) [b]	2019	0.500	17.10	2.084	2.306	1.550	0.800	-5.867	**<0.001***	0.67
	2020	0.300	2.500	1.042	0.411	0.950	0.700			
NO_2 (ppb) [b]	2019	13.80	37.30	30.35	9.756	28.35	12.97	-7.181	**<0.001***	0.82
	2020	5.200	56.60	13.97	6.366	12.00	9.300			
O_3 (ppb) [a]	2019	12.10	79.20	45.16	16.68	45.55	24.90	0.975	0.332	0.16
	2020	1.400	75.80	42.62	15.63	44.45	22.32			
CO (ppm) [b]	2019	1.140	2.915	1.747	0.380	1.664	0.585	-6.762	**<0.001***	0.78
	2020	0.620	2.500	1.152	0.307	1.113	0.300			
Wind Direction(°)[b]	2019	218.3	359.8	328.4	27.69	331.6	33.51	-2.107	**0.035***	0.24
	2020	92.52	358.9	307.3	58.63	329.0	49.06			
Wind Speed (m/s)[b]	2019	1.240	8.620	5.070	2.160	5.348	3.660	-3.666	**<0.001***	0.42
	2020	0.870	8.530	3.702	2.043	3.112	3.550			
Relative Humidity (%) [b]	2019	79.07	98.00	92.03	5.337	92.68	9.100	-3.071	**0.002***	0.35
	2020	86.52	98.40	94.09	3.600	94.55	5.320			
Solar Radiation (W/m^2)[b]	2019	378.5	886.8	705.0	112.4	716.2	148.9	-5.954	**<0.001***	0.68
	2020	138.6	784.4	564.5	124.8	597.7	149.1			
Ambient temperature (°C) [b]	2019	32.35	36.37	34.48	1.065	34.60	1.700	-0.958	0.338	0.11
	2020	28.77	36.94	34.60	1.347	34.81	1.360			

a=paired t-test b= Wilcoxon signed rank test, *significant at $p<0.05$

Table 4.2. Descriptive statistics and differences analysis of air pollutants and meteorological data in Selangor

Variables	Year	Min	Max	Mean	SD	Median	IQR	t or Z	p	d or r
PM_{10} (µg/m^3) [b]	2019	32.51	125.2	55.44	17.60	50.67	13.35	-6.441	**<0.001***	0.74
	2020	21.45	76.71	37.23	10.79	35.88	12.29			
$PM_{2.5}$ (µg/m^3) [b]	2019	24.43	107.3	41.84	16.21	36.62	13.38	-5.633	**<0.001***	0.65
	2020	16.71	63.32	29.79	8.903	28.12	8.355			
SO_2 (ppb) [b]	2019	0.900	14.40	2.424	2.235	1.900	0.800	-2.748	**0.006***	0.32
	2020	0.400	19.30	1.950	2.417	1.200	1.480			
NO_2 (ppb) [b]	2019	22.00	59.20	38.50	9.308	38.25	14.20	13.078	**<0.001***	2.02
	2020	5.600	60.70	19.63	9.409	17.25	10.18			
O_3 (ppb) [a]	2019	17.70	90.60	49.46	16.60	50.35	22.80	5.629	**<0.001***	0.90
	2020	2.200	55.80	37.37	10.15	38.45	13.55			
CO (ppm) [b]	2019	1.232	3.213	2.125	0.452	2.101	0.625	14.212	**<0.001***	2.33
	2020	0.483	3.264	1.099	0.428	0.960	0.445			
Wind Direction(°)[b]	2019	209.8	359.2	308.9	40.36	320.1	69.28	-0.502	0.616	0.06
	2020	204.2	358.4	300.6	42.55	307.1	66.33			
Wind Speed (m/s^1)[b]	2019	1.029	5.954	1.854	0.796	1.737	0.686	-0.241	0.81	0.03
	2020	0.636	3.512	1.817	0.581	1.733	0.805			
Relative Humidity (%) [b]	2019	76.84	98.00	92.86	4.185	93.65	7.093	-0.767	0.443	0.09
	2020	82.58	98.00	93.55	4.077	94.46	6.592			
Solar Radiation (W/m^2)[b]	2019	298.8	829.6	655.2	112.5	680.6	144.0	-6.14	**<0.001***	0.70
	2020	128.9	661.8	514.0	107.5	536.4	132.9			
Ambient temperature (°C) [b]	2019	31.42	37.09	34.42	1.181	34.54	1.600	-0.465	0.643	0.07
	2020	29.21	36.76	34.51	1.435	34.76	1.886			

a=paired t-test b= Wilcoxon signed rank test, *significant at $p<0.05$

Only records data of Batu Muda stations is analysed in depth because it was located in the major communities in Kuala Lumpur with higher COVID-19 cases and only Petaling Jaya station for Selangor state because it covers the high population and industrial area in Selangor. All six air pollutants parameters were compared with the new Malaysia Ambient Air Quality Standard for 2020 Department of Environment Malaysia (2020). Neither of these air pollution parameters expected to exceed the standards (PM_{10} = 100 µg/m3 24 hours, $PM_{2.5}$ = 35 µg/m3 24 hours, SO_2 = 95 ppb 1 hour, NO_2 = 149 ppb 1 hour, O_3 = 92 ppb 1 hour, CO = 26.19 ppm 1 hour) except for $PM_{2.5}$ for both states.

Figure 3 and Figure 4 represents the average weekly levels of air pollutants and meteorology factors in Kuala Lumpur and Selangor respectively from 18 March to 1 June 2019 compared to the same period for 2020. Week 1 was from 18 to 24 March, Week 2 was from 25 to 31 March, Week 3 was from 1 to 7 April 2020, Week 4 was from 8 to 14 April, Week 5 was from 15 to 21 April, Week 6 was from 22 to 28 April, Week 7 was from 29 April to 5 May, Week 8 was from 6 to 12 May, Week 9 was from 13 to 19 May, Week 10 was from 20 to 26 May while Week 11 was from 27 May to 1 June.

Figure 3 shows a similar decreasing trend during the MCO compared to the same time period in 2019 for all air pollutants except O_3. At the earlier week of MCO $PM_{2.5}$ and PM_{10} in 2020 become lower trend but become higher trend during the week 8 until week 11. The highest reading of PM_{10} is 68.29 µg/m^3 in Week 10 and 79.26 µg/m^3 in Week 9 for $PM_{2.5}$. $NO_{2,}$ SO_2, and CO showed lower trends during the MCO than 2019. While, SO_2

showed fluctuate reading during MCO and remain lower than 2019. However, for meteorological factors, WD show no apparent different between these two years. RH and AT show higher trend in 2020 compared to 2019. similar trend was observed in in these two years, there was no apparent difference between WD, WS, RH and AT. Nevertheless, WS show slightly lower trend during MCO and SR exhibited a lower trend than in 2019 for all week.

The figure 4.3 showed that mostly air pollutants concentrations on 2020 which is MCO was implement have lower trends than concentrations on 2019. At the earlier week of MCO, SO_2 have lower trend but drastically higher on week 11 which is 5.75 ppb. NO_2 and CO concentration have drop more than 50% during the MCO compared to 2019. However, observation for meteorological factors, there was no apparent difference between WD concentration trends. WS, RH and AT had various of trend within these thirteen weeks while SR shows the declined trends in 2020 compared to 2019.

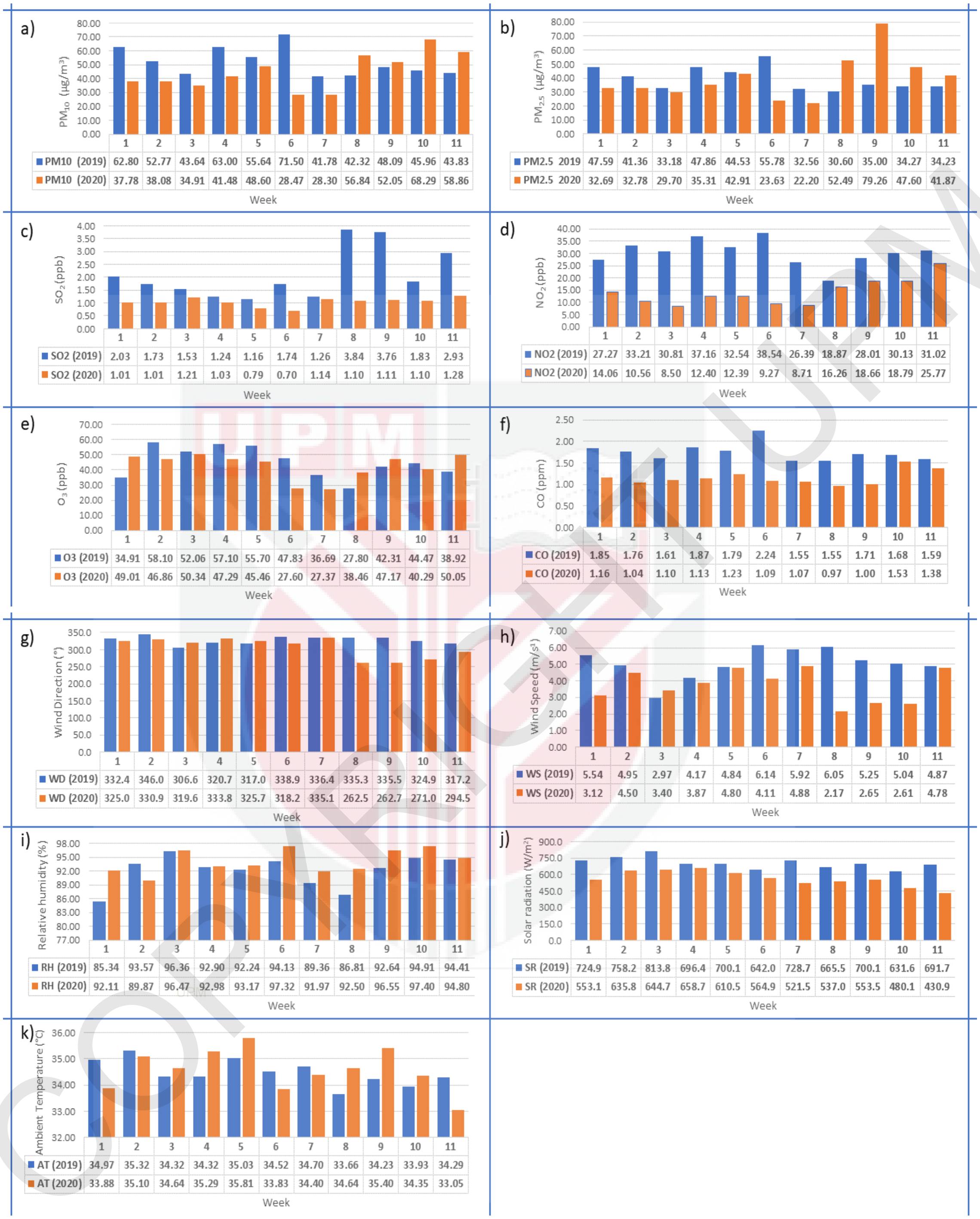

Figure 4.3. (a) PM_{10} (µg/m^3), (b) $PM_{2.5}$ (µg/m^3), (c) SO_2 (ppb), (d) NO_2 (ppb), (e) O_3 (ppb), (f) CO (ppm), (g) WD (°) (h) WS (m/s), (i) RH (%), (j) SR (W/m^2) and AT (°C) in Kuala Lumpur from 18 March to 1 June for both 2019 and 2020

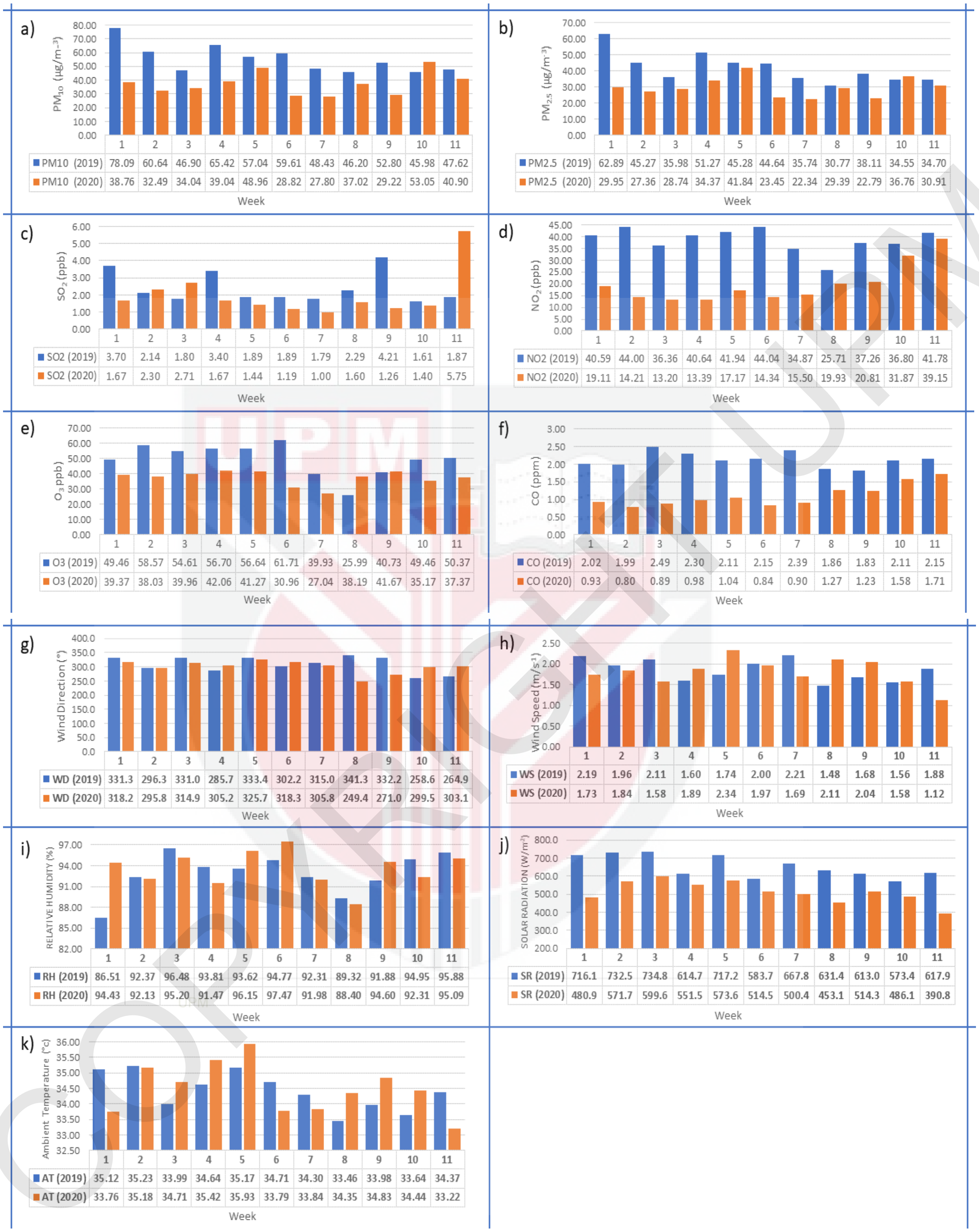

Figure 4.4. (a) PM_{10} (µg/m^3), (b) $PM_{2.5}$ (µg/m^3), (c) SO_2 (ppb), (d) NO_2 (ppb), (e) O_3 (ppb), (f) CO (ppm), (g) WD (°) (h) WS (m/s), (i) RH (%), (j) SR (W/m^2) and (k) AT (°C) in Selangor from 18 March to 1 June for both 2019 and 2020

Figure 4.5 and Figure 4.6 indicate the weekly average levels of air pollutants and meteorological factors beginning from 4 March to 1 June 2020 (13 weeks) in Kuala Lumpur and Selangor respectively. the measurements were categorized into two periods, before the MCO (4 March 2020 to 17 March 2020) (Week 1& 2) and during the MCO (March 18 to 1 June 2020) (Week 3-week 13). Week 1 was from 4 March to 10 March, Week 2 was 11 March to 17 March, Week 3 was from 1 March to 18 to 24 March, Week 4 was from 25 to 31 March, Week 5 was from 1 to 7 April 2020, Week 6 was from 8 to 14 April, Week 7 was from 15 to 21 April, Week 8 was from 22 to 28 April, Week 9 was from 29 April to 5 May, Week 10 was from 6 to 12 May, Week 11 was from 13 to 19 May, Week 12 was from 20 to 26 May while Week 13 was from 27 May to 1 June.

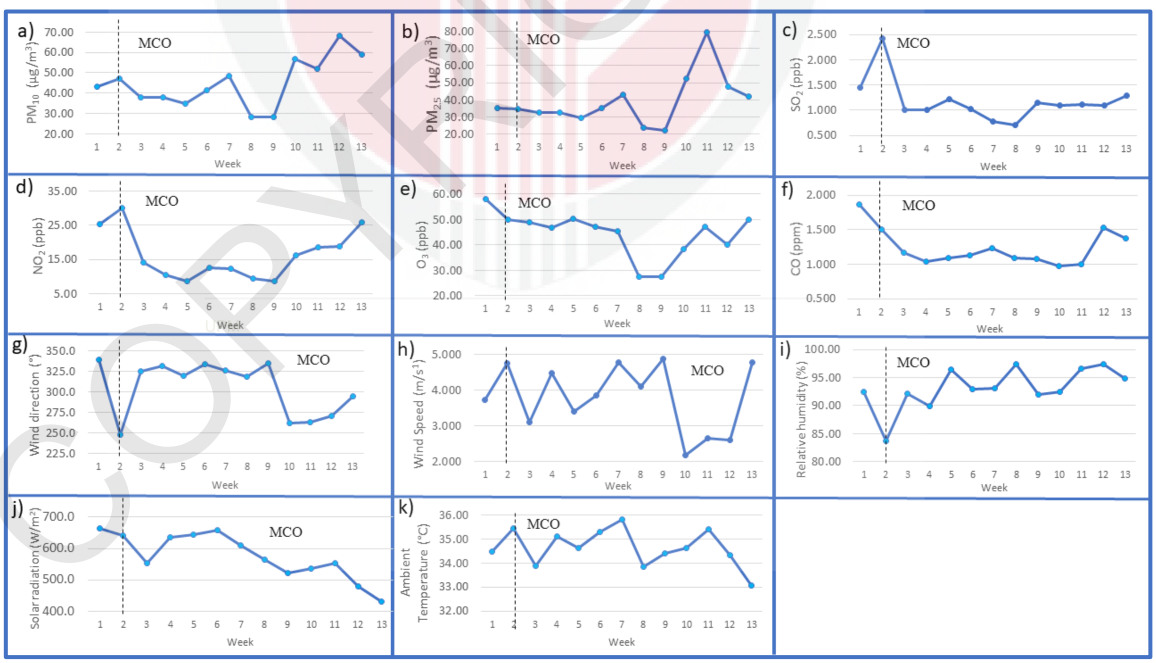

Figure 4.5. (a) PM_{10} (µg/m^3), (b) $PM_{2.5}$ (µg/m^3), (c) SO_2 (ppb), (d) NO_2 (ppb), (e) O_3 (ppb), (f) CO (ppm), (g) WD (°) (h) WS (m/s), (i) RH (%), (j) SR (W/m^2) and (k) AT (°C) in Kuala Lumpur from 4 March 2020 (before MCO) to 1 June 2020 (during MCO)

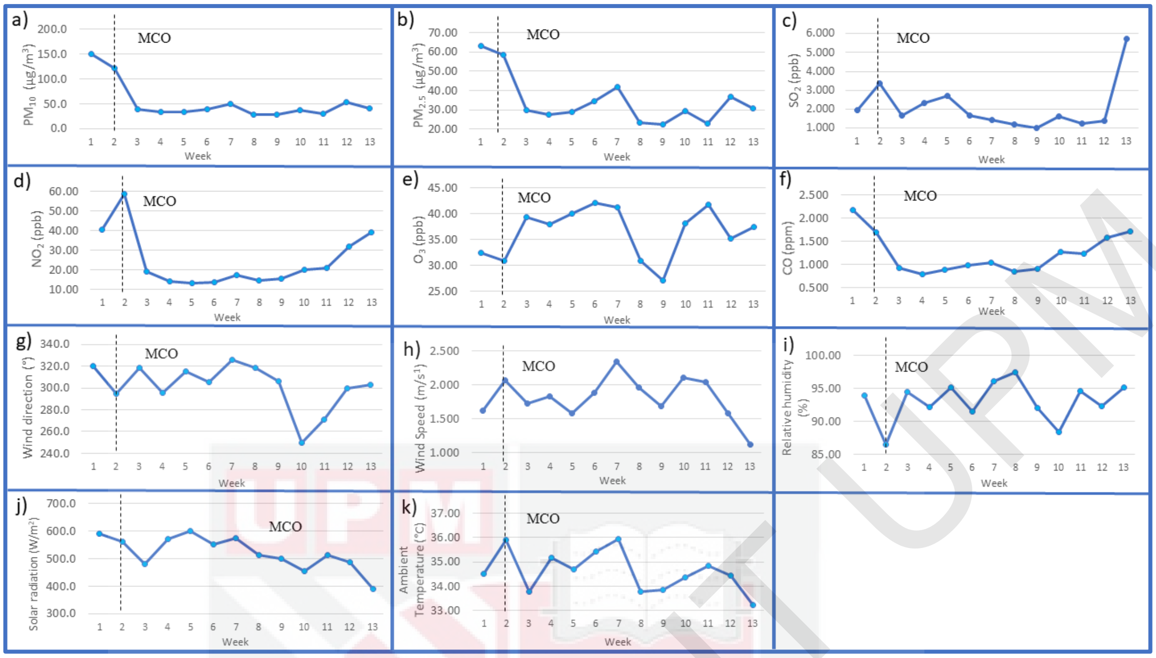

Figure 4.6. (a) PM_{10} (μg/m^3), (b) $PM_{2.5}$ (μg/m^3), (c) SO_2 (ppb), (d) NO_2 (ppb), (e) O_3 (ppb), (f) CO (ppm), (g) WD (°) (h) WS (m/s), (i) RH (%), (j) SR (W/m^2) and (k) AT (°C) in Selangor from 4 March 2020 (before MCO) to 1 June 2020 (during MCO).

What's remarkable in these statistics is that MCO's first week (Week 3) and the MCO's second week (week 4) demonstrated a significant reduction in all air pollutants exclude for $PM_{2.5}$ and O_3 in Kuala Lumpur and only O_3 in Selangor. In Kuala Lumpur, PM_{10} and $PM_{2.5}$ concentrations were not noticeable decrease after MCO during the week 3 until week 5 but were increase drastically in week 10 while for Selangor have lower trends and clearly decreasing concentrations which is from range 151-120.9 μg/m^3 before MCO and drop within range 53.1-29.2 μg/m^3 during MCO for PM_{10} concentrations and from range 62.8 -58.2 μg/m^3 before MCO and drop until range 41.8- 22.3 μg/m^3 during MCO for $PM_{2.5}$.

Reductions of PM_{10} and $PM_{2.5}$ have been recorded at 31% and 43% during the lockdown time in India, which described the impacts of human activity restrictions and shutdown (Sharma et al., 2020b). Furthermore, there are industrial area and heavy road traffic around the monitoring station, so that when MCO was implement the restriction of movement and operational of industrial also have been stop and decrease the production of particulate matters. During the MCO, lorries used to transport food and essential goods were not strictly limited and therefore the concentrations of $PM_{2.5}$ and PM_{10} could result from these transport operations for the Kuala Lumpur region (Othman & Latif, 2021). This explained why concentrations of PM_{10} and $PM_{2.5}$ were not clearly decrease during MCO in Kuala Lumpur.

As a result of reduced manufacturing activity in Malaysia throughout MCO, SO_2 concentrations were also decrease, but on Week 13 in Selangor the SO_2 concentration increase drastically. It is because of many industrial activities have been fully operate due Conditional Movement Control Order (CMCO) that allow most economic sectors and activities to operate. Concentration of CO_2 and NO_2 obviously recognized higher concentrations before MCO than during MCO in both states. Significant reductions in NO_2 and CO emissions be likened with limited movement following the MCO implementation to the decreased number of vehicles on the road when human movements are reduced. These cities are next to each other and normally have large volumes of motor cars used on an average day between these cities. Several study reported CO reduction in Delhi's megacity and decline in NO_2 levels in the of Rio de Janeiro city to be due to closed road and reduction of vehicle movement, and closed manufacturing factories and power plant during COVID-19 lockdown (Dantas et al., 2020; Mahato et al., 2020).

Lefohn et al. (2017) and Paoletti et al. (2014) indicate that the reduction of NOx concentration had a positive trend of O_3 with in some cities. In contrast, study from Tiwari et al. (2015) and Wang et al. (2014) stated that concentration of O_3 fell rapidly at higher concentrations of NOx. With the presence of sunlight, photolysis of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) produces ozone (Fang et al., 2020). Low O_3 consumption due to lower NO_2 emissions caused by limited industrial activity and vehicles being off the road during the lockdown phases may contribute to an increase in O_3 concentration (Sharma et al., 2020a; Tobías et al., 2020a).

In term of meteorological factors, during the first week of MCO shows a reduction concentration in all variables exclude for RH and WD. The RH increase is expected to continue until May 2020 as a result of the monsoon season that can cause rain frequently. Throughout the year, climate in Malaysia is classified as hot and humid as its position near the equator. Throughout the research period between March and April, Malaysia experienced an inter-monsoon season and an in early May will experience early stage of the Southwest (SW) monsoon. Generally, the average of the WS, RH, SR and AT were in the range of 3.72 to 4.76 m/s^1, 83.7 to 92.5 %, 639.9 to 664.0 W/m^2 and 34.47 to 35.43°C, respectively, before the MCO in Kuala Lumpur and 1.62 to 2.06 m/s^1, 86.5 to 93.9%, 560.8 to 592.1 W/m^2 and 34.5 to 35.91°C, respectively, before MCO in Selangor.

Nonetheless, the average of WS indicates a slightly decreasing trend (2.17 to 2.65 m/s^{1}) at the end of the MCO for Kuala Lumpur and 1.11 to 2.33 m/s^{1} in Selangor, where the seasonal changes might be attributed. The RH shows a slightly higher patterns during the MCO when compared to before the MCO with a range of 89.87 to 97.40 % in Kuala Lumpur and 88.40 to 97.47% in Selangor. While, the ambient temperature during MCO phases shows similar trends for both state which higher trends in earlier of MCO but lower trends at the end of MCO week that reach to 33°C.

These restrictions are not just to control the outbreak of COVID-19 disease but also to minimize air pollution in Malaysia. According to the findings, the MCO was successful in reducing pollutant emissions, especially NO_2 and CO levels, because there were fewer motor vehicles and industrial activity during the MCO. Study from others country also explain about reduction of air pollution during restriction in their country. For example, a study from Sahoo et al. (2021) shows a significant reduction for NO_2 levels during lockdown periods, with the greatest reduction in densely populated and heavily trafficked areas in Chhatrapati Shivaji International Airport. Thus, shutting down transport and in-industrial sectors is the main explanation why these pollutants declined sharply during the lockdown phases. Start from 4 May 2020 Malaysia has announced Recovery Movement Control Order that allow most economic sectors and activities to operate while observing the business standard operating procedures (SOP). This explains why certain air pollution parameters change concentrations trends from Week 6-7 until the end of the Week 11 compared with concentrations before earlier MCO.

The findings of this study aligned with a previous research by Nadzir et al. (2020), that reporting low levels of assessed contaminants ($PM_{2.5}$, PM_{10} and CO) during the MCO era in Klang Valley, Malaysia. While study from other country such as Indian (Delhi) and Spain (Barcelona) also reporting the reduction on $PM_{2.5}$, PM_{10}, CO and NO_2 also increasing of O_3 during the shutdown (Mahato et al., 2020; Tobías et al., 2020b). Several studies from major cities in China and Morocco showed a significant reduction in air pollutants such as $PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO during COVID-19 lockdown (Otmani et al., 2020; Zhu et al., 2020a). Aside from that, many Indian studies the outbreak, particularly between late March and April (Sarkodie & Owusu, 2020)) (Gautam et al., 2021) and also studies on air quality and lockdown that shown it the sharp decline of air pollutants due to shutdown applied during the outbreak, (Bherwani et al., 2021; Gautam et al., 2020; Gupta et al., 2021).

4.3 Relationship between air quality, meteorological factors and COVID-19 cases

COVID-19 has of 1 to 14 days of incubation period (CDC, 2020) and the impact of meteorological parameters could last for a few days (Elengoe, 2020a). Study by Travaglio et al. (2020) investigate correlations between total COVID-19 cases and deaths and concentrations air pollutants of year that when no COVID-19 cases were identified. As a result, it was reasonable for to apply the lag effect of various air quality and meteorological variables in this study. Assuming that the usual duration from virus transmission to infection is seven days, the average daily air quality and meteorological parameters of seven days ago have been compared with total reported cases of MCO day. Example of correlation, COVID-19 cases on 18 March 2020 against average air quality on 11 March 2019 (Suhaimi et al., 2020) and 11 March 2020 on meteorological factor parameter. Spearman's correlation tests were used as bivariate correlation coefficient (r) to determine the correlations between COVID-19 and air quality and meteorological parameters in this study. For all statistical analyses, a p-value of less than 0.05 was considered significant.

Table 4.3 shows correlation of air pollutants parameter and meteorological variables with cumulative COVID-19 cases in Kuala Lumpur. Among air pollutant variables, only PM_{10}, $PM_{2.5}$ and NO_2 shows an important association with COVID-19 while meteorological factors variables only WS, RH and SR have significant correlations with COVID-19 cases. SO_2, O_3, WD and AT did not show any significant correlations with COVID-19 infections. COVID-19 cases had weak positive significant correlations with $PM_{2.5}$, PM_{10}, NO_2. In addition, RH indicate a strong significant positive correlation with COVID-19 cases. However, WS and SR have negative significant correlations with COVID-19 infections. Furthermore, COVID-19 infections that have been reported were statistically significant on outdoor air pollution and meteorological factors.

Table 4.3. Spearman's correlation tests between daily air pollutants and meteorological factors data with cumulative COVID-19 cases in Kuala Lumpur.

Variables	r	p
PM_{10} (µg/m^3)	0.281	**0.014***
$PM_{2.5}$ (µg/m^3)	0.352	**0.002***
SO_2 (ppb)	0.086	0.462
NO_2 (ppb)	0.245	**0.033***
O_3 (ppb)	0.182	0.115
CO (ppm)	0.116	0.320
Wind Direction (°)	-0.151	0.192
Wind Speed (m/s)	-0.311	**0.006***
Relative Humidity (%)	0.494	**<0.001****
Solar Radiation (W/m^2)	-0.368	**0.001****
Ambient temperature (°C)	-0.021	0.857

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

The following factors at a multivariate level were examined by a multiple linear regression at bivariate levels were statistically significant. It has six predictor variables (PM_{10}, $PM_{2.5}$, NO_2, WS, RH and SR). The stepwise method fitted with only one variable in the final model. Table 4.4 identifies variable that correlate with total COVID-19 cases in Kuala Lumpur. From the analysis results it revealed RH was the most contributed of meteorological influencing the occurrence of COVID-19 in Kuala Lumpur. The following is the equation in Equation 1:

$$\text{Total COVID-19 cases} = 2547.834 + 47.835 \text{ (RH)} \_\_\_\_\_ \text{ (Equation 1)}$$

Table 4.4. Multiple linear regression for associations between Relative humidity with cumulative COVID-19 cases in Kuala Lumpur.

Independent Variables	B (SE)	Standardized Coefficients	*p*	95% CI	VIF
Constant	2547.834 (1157.542)	-	0.031	239.190 to 4856.478	-
Relative Humidity (%)	47.835 (11.294)	0.424	<0.001*	25.309 to 70.360	1.129

*Significant at $p < 0.05$, Method = Stepwise, $R^2 = 0.379$, Adjusted $R^2 = 0.334$, 95% CI = 95% Confidence Interval, B = Regression Coefficient, SE = Standard Error, VIF = Variance Inflation Factor.

For every unit of 1% increase in RH COVID-19 cases will increase by 47.835. Beta values were significant at 0.05. VIF readings were less than 5, which showed no multicollinearity concern. 33.4 % of variance in COVID-19 cases could be explained by RH, $R^2 = 0.379\%$, $F(5, 70) = 8.54$, $p < 0.001$. This can be presumed large combined effect ($f^2 = 0.61$), thus showed RH as the big contribution in COVID-19 cases. Many of the factors that are not mentioned in this study are important for the occurrence of COVID-19.

Table 4.5 shows the correlations between air pollutants and meteorological variables with cumulative COVID-19 cases in Selangor. Among air pollutant variables, $PM_{2.5}$, PM_{10}, NO_2, and O_3 had significant correlation with COVID-19 cases in Selangor while SO_2 and CO shows no significant correlation. In addition, for meteorological variables, only SR was significant correlation with COVID-19 cases while WD, WS, RH and AT had no significant. COVID-19 cases had weak significant positive correlations between PM_{10}, $PM_{2.5}$, NO_2, and O_3 while, weak significant negative correlations of SR. Up to this point, the impact of outdoor air pollution levels and meteorological conditions on COVID-19 infections have been statistically significant.

Table 4.5. Spearman's correlation tests between hourly air pollutants and meteorological data with cumulative COVID-19 cases in Selangor.

Variables	***r***	***p***
PM_{10} (µg/m^3)	0.354	0.002**
$PM_{2.5}$ (µg/m^3)	0.396	< 0.001**
SO_2 (ppb)	0.070	0.550
NO_2 (ppb)	0.263	0.022*
O_3 (ppb)	0.306	0.007*
CO (ppm)	0.067	0.563
Wind Direction (°)	-0.191	0.099
Wind Speed (m/s)	0.037	0.748
Relative Humidity (%)	0.030	0.798
Solar Radiation (W/m^2)	-0.249	0.030*
Ambient temperature (°C)	-0.175	0.131

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Next, by using multiple linear regression, it had five predictor variables (PM_{10}, $PM_{2.5}$, NO_2, O_3 and SR). When the model was fitted with the stepwise method, only variable with the significant p-value <0.05 were selected from this model. Table 4.6 shows one variable that represents air quality variables that were strongly linked to cumulative COVID-19 cases in Selangor. $PM_{2.5}$ was the most significant air pollutant influenced the incidence of COVID-19 cases in Selangor by using multiple linear regression. The equation portrayed in Equation 2 below:

$$\text{Total COVID-19 cases} = 1885.261 + 13.246\ (PM_{2.5}) \text{ \_\_\_\_\_ (Equation 2)}$$

Table 4.6. Multiple linear regression for associations between $PM_{2.5}$ a cumulative COVID-19 cases in Selangor

Independent Variables	B (SE)	Standardized Coefficients	p	95% CI	VIF
Constant	1885.261(325.310)	-	< 0.001*	1236.612 to 2533.909	-
$PM_{2.5}$ (µg/m^3)	13.246 (3.605)	0.471	< 0.001*	6.058 to 20.433	1.541

*Significant at $p < 0.05$, Method = Stepwise, $R^2 = 0.244$, Adjusted $R^2 = 0.201$, 95% CI = 95% Confidence Interval, B = Regression Coefficient, SE = Standard Error, VIF = Variance Inflation Factor.

For every unit (1 µg/m^3) increase in $PM_{2.5}$, COVID-19 cases will increase by 13.246. Beta values were significant at 0.05. VIF readings were less than 5, which showed no multicollinearity concern. 20.1 % of variance in COVID-19 cases can be explained by $PM_{2.5}$, $R^2 = 0.244$, $F (4, 71) = 5.72$, $p < 0.001$. A combined effect of this magnitude can be considered large ($f^2 = 0.73$), hence $PM_{2.5}$ have the large contribution in COVID-19 cases.

Our findings demonstrate a link between COVID-19 cumulative cases, air contaminants, meteorological factors, and their relations. Scientific study is supporting evidence that chronic illnesses are linked to environmental pollution, particularly in urban areas. Air pollution is a well-known contributor to chronic inflammation, which ultimately results in an overactive innate immune system. (Conticini et al., 2020). The recent SARS infection in China, where prolonged air pollution predicted adverse outcomes in SARS patients (Cui et al., 2003). Long-term air pollution exposure can lead persistent immune system disturbances (Tsai et al., 2019) and may result to weakened circulatory and respiratory viral invasion, thus increasing the risk of severity outcome of COVID-19 (Conticini et al., 2020; Kulkarni et al., 2020). In our study, correlation test shown air pollutant parameters PM_{10}, $PM_{2.5}$, NO_2 and O_3 have positive significant correlation.

As a result, we compared our major findings to past research to see if there were any similarities or variations. This finding were comparable with previous study showing that it have contrast finding by Sahoo et al. (2021) in India, Zhu et al. (2020a) in China and Bashir et al. (2020) in California, that reported the majority of air pollutants (PM_{10}, $PM_{2.5}$ and NO_2,) are negatively significant correlated with COVID-19 cases and have significantly negatively correlated between O_3 and daily confirmed number of COVID-

19 cases (Lorenzo et al., 2021). While, a study were in line with our finding that show a positive relationship between O_3 and cumulative COVID-19 cases was in line with previous Chinese study that found a positive relationship (Zhu et al., 2020b). A study discovered that a rise in the long-term average of ozone is linked to COVID-19 mortality and morbidity (Travaglio et al., 2020).

$PM_{2.5}$ and PM_{10} are the air pollution factors that have been related to a number of health effects, including inflammatory responses, oxidative damage, and DNA damage, as well as respiratory, cardiovascular, and nervous system problems. (Zoran et al., 2020). $PM_{2.5}$ has the potential to impair bronchial immunity and epithelial cell integrity (Jiang et al., 2020) reducing the antibodies to fight viruses and developing impacted in increasing the susceptibility to respiratory disease. Hence, my studies shows a positive correlation of $PM_{2.5}$ and PM_{10} with cumulative COVID-19 cases in line with study in Milan (Zoran et al., 2020) that show positive correlation with COVID-19 daily cases.

It had been proven that the NO_2 SO_2, and CO emissions were connected to an increased prevalence of cardiovascular disease infections (Chen et al., 2007). However, my finding had no significant correlation of SO_2 and CO with cumulative COVID-19 cases. In healthy volunteers, chamber research findings shown that atmospheric nitrogen dioxide causes inflammatory cells to infiltrate the airways (Ghio et al., 2000). Furthermore, study in England shows the exposure to such pollutants could prevent pulmonary antimicrobial responses, limiting virus clearance from the lungs and increasing infectivity (Travaglio et al., 2020). They also state that 3.3% cases and 3.1% deaths was linked with increasing in 1 mg/m3 of nitrogen dioxide concentration in 2018. Therefore, we discovered positive relationships between NO_2 and cumulative COVID-19 occurrences in our research that we in line with study in Italy and China, reported the daily COVID-19 cases where positively associated with NO_2 (Frontera et al., 2020; Zhu et al., 2020b).

Meteorological factors parameters are considered to be effective determinants for viability, transmission and range of virus transmission (Chan et al., 2011; van Doremalen et al., 2013). Researchers have predicted for decades that climate change may have an effect on the epidemiology of infectious diseases (Casadevall, 2020). From our finding, the meteorological factors WS, RH and RH were correlated with cumulative COVID-19 cases in Kuala Lumpur and Selangor. Study from Jordan also reported relationship between WS, RH and RH in their finding. There was identified to have a higher rate of infection with low levels of wind speed, humidity, and solar radiation, promoting the survival of the virus (Abdelhafez et al., 2021). In addition, these meteorological factors also can have an impact on droplet stability in the environment, or on virus survival and hence on epidemic transmission (Chen et al., 2020b).

In our study, we observed moderate positive correlation between RH and COVID-19 cases ($r = 0.\ 0.494$, $p < 0.001$) in that means the COVID-19 cases will increase when RH increase. Our findings are consistent with those in India (Gautam et al., 2021). They stated that cumulative cases are increasing rapidly with RH. While in environments with lesser humidity which is dry, the immune response to viruses is less efficient. Similarly, in Singapore and Thailand that were neighborhood with Malaysia also show significant positive correlation of RH with the daily COVID-19 cases (Pani et al., 2020b; Sangkham et al., 2021). However , Wu et al. (2020) represent negatively associated of relative humidity with daily new COVID-19 cases. As a result, our findings show that high relative humidity aided COVID-19 spread in tropical nations like Malaysia, Singapore, and Thailand, but not in colder regions like Europe and the United States (Suhaimi et al., 2020).

SR has negative correlation but have weak correlation with COVID-19 cases in Kuala Lumpur ($r = -0.368$, $p = 0.001$) and Selangor ($r = -0.249$, $p = 0.030$). This suggests that the number of confirmed cases is reduces with Solar Radiation. Sunrise ultraviolet rays in the summer may be important for preventing the disease of the coronavirus because UV light could damage or destroy different varieties of virus like SARS and MERS (Türsen et al., 2020). In other explanation, the number of confirmed cases is increase with lower concentration of solar radiation This may due to my study period there were monsoon season that can cause cloud cover the sun and lead to decreasing in Solar Radiation concentration (Figure 4.4(j) &Figure 4.5(j)). A study in the USA by Merow & Urban, (2020) stated that growth of SARS-CoV-2 can be promoted in lower ultraviolet rays. The findings of a study in Jordan, which established an adverse correlation between solar radiation and COVID-19 cases and said that solar radiation plays a crucial role in COVID-19 outbreaks, match with our findings (Abdelhafez et al., 2021).

Meteorological factors overall contributed more to SARS-CoV-2 transmission in regions and months with colder and drier conditions and lower UV radiation than in regions and months with warmer, wet seasons and higher UV radiation levels (Ma et al., 2021). In addition, hot and dry weather can reduce infections generated by droplet contact, but the chance of transmissions via aerosol particles is raised while for cool and humid weather can efficiently prevent the formation of aerosol particles, but it also promotes the distribution of large droplets (Zhao et al., 2020).

WS has negative correlation with COVID-19 cases in Kuala Lumpur (r = -0.311, p = 0.006) but had not significant in Selangor. According to other research, there is a negative relationship between wind speed and the rate of incidents (Alkhowailed et al., 2020). They also claim that COVID-19 transmission is influenced by wind speed in cities with a high population could be due to a low in wind speed in these areas favoring the spread of SARS-COV-2 virus among persons living in close proximity and congested areas as compared to areas with a higher wind speed. However, in Africa COVID-19 has a positive association with wind speed (Adekunle et al., 2020).

A spike glycoprotein on the coronavirus envelope can attach to certain membrane receptors (Ni et al., 2020). SARS-CoV-2 attacks lung cells and other organs then attaches to ACE2 on cells, enabling viral entry. SARS-CoV-2 affects several organs with high ACE2 expression because ACE2 is highly expressed in numerous organs and tissues. A study also shown that SARS-CoV-2 can penetrate ACE2-expressing cells (Zhou et al., 2020). A study from Paital & Agrawal, (2021) shows that severity of disease can be shown by the level of ACE2. The higher the level of ACE2 the higher the severity of COVID-19 disease.

CHAPTER 5

CONCLUSION

Air pollution concentrations may be caused by socioeconomic and industrial development, and the correlations between daily climate conditions and the distribution of COVID-19 may vary. Many countries were prompted to impose full or partial lockdowns as a result of the COVID-19 pandemic, resulting in a significant drop-in anthropogenic activity due to the prohibition of outdoor invasion, which reduced the number transportation and the closure of industry. The government's most crucial decision to break the COVID-19 chain within the community was to implement an MCO. This difficult decision has clearly touched all sectors, particularly the economy, from the lowest levels of individual income to the highest levels of international trade. On the one hand, it caused people to suffer, but on the other hand, it benefited the environment by reducing atmospheric pollution.

Initially, the levels of several pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO) indicated a sharp decline in concentration early after the lockout. Conditional Movement Control Order (CMCO) were imposed, the levels increased again. In comparison with 2019 and 2020, all air pollution and meteorological factor parameters except $PM_{2.5}$, O_3 and AT were significantly reduced in Kuala Lumpur. In Selangor, there is a significant reduction in all air pollutant parameters and only SR for meteorological factors. This concludes that during the COVID-19 outbreak restriction, air pollutant levels are significantly reduced.

A link between air pollution, meteorological conditions, and COVID-19 instances is observed in this study. To investigate the association between long-term exposure to air pollutant concentrations, meteorological factors, and COVID-19 cases in Kuala Lumpur and Selangor, the nonparametric Spearman's correlation was performed. The COVID-19 shows a week and positive correlation with PM_{10} (r=0.281, p=0.014), $PM_{2.5}$ (r=0.352, p=0.002) and NO_2 (r=0.245, p=0.033) in Kuala Lumpur. In Selangor, COVID-19 shows a weak and negative correlation with PM_{10} (r=0.354, p=0.002), $PM_{2.5}$ (r=0.396, p<0.001), NO_2 (r=0.263, p=0.022) and O3 (r=0.306, p=0.007). The outcomes also indicate that cumulative cases are increasing with WS (r=-0.311 and p=0.006), RH (r=0.494 and p<0.001), SR (r=-0.249 and p<0.001) in Kuala Lumpur SR (r=-0.368 and p<0.001) in Selangor.

It was found that most significant air pollutant and meteorological factors that influenced the infection rate of COVID-19 using multiple linear regression at the multivariate level. The most significant air pollutant and meteorological factors with total cases of COVID-19 in the Kuala Lumpur are the RH (r = 0.494; p<0.001) and followed by $PM_{2.5}$ (r=0.396, p<0.001) in Selangor, while other variables failed.

According to the findings, Malaysian government's efforts to control the COVID-19 outbreak have a significant impact on air pollution levels in the country. Furthermore, it is possible to argue that lower human outdoor activities, automobile emissions, and coal-fired power plant emissions all contribute to cleaner air. Thus, the lesson learned during this COVID-19-related lockdown could act as a catalyst for policymakers to consider using it as baseline level for developing strategies to improve air quality or managing air pollutants in metropolitan regions that are typically neglected, either directly or indirectly (Masum & Pal, 2020).

5.1 LIMITATION

This study has some limitations. First, only two states are identified, which may result in some results deviating from the actual influence of ambient pollution and meteorological conditions on SARS-CoV-2 transmission in Malaysia. Second, the number of stations taken was only one for the whole state. Then, only 11 weeks data were used to compare during no COVID-19 cases were reported and during COVID-19 present and also only year 2020 were used to represent long term exposure of air pollutant due to availability of data. Moreover, because of the ecological study design used in this study, it is possible that it contains ecological fallacy to some extent. Individual-level data on air pollutant exposure and meteorological variables were not collected, resulting in assumptions limited for group-level analysis of available data. Not every person who infected with covid-19 because of air pollution and meteorological factor exposure. It could be because of non-hygienic practices, social distancing and non-proper face mask wearing.

5.2 RECOMMENDATION

In future study, we will enroll more stations to represent whole state and consider a long period of study. Also, will compared with multiple countries and areas to validate the results from current study. By considering more stations might give better results. For study period, considering long period of study which is increased number of weeks might give better result to determine the relationship between air quality and meteorological data with COVID-19 cases. Other than that, number of years to determine the long terms exposure of air quality also can be improved to gain better average to represent the year without COVID-19 and with COVID-19 for example use four years back (2016-2020) air pollution data to represent long term exposure of air pollutant. The aims of green environmental policy should include for saving the lives of infants, children, and the elderly, who are particularly vulnerable to infectious disease outbreaks. Malaysia can establish systematic pollution-based policies and characteristics in each city. For example, new vehicle technology or enhanced uses of public transport as most cities' air quality improved as vehicle numbers decreased throughout the MCO period. Furthermore, each mitigation measures to lower air pollution concentrations on a limited scale, possible to expanding to a greater scale in the future.

Result from this study would lead to new hypotheses for future research in epidemiology and the COVID-19 pandemic dynamics in same season of country. Further study such as cohort studies, should be conducted to investigate the causes of disease, taking into account age, gender, underlying conditions, and vulnerable groups (people with asthma, chronic obstructive pulmonary disease (COPD), diabetes, cardiovascular diseases or tuberculosis (TB). However, during this epidemic, precautions such as physical separation, handwashing with soap, and using a 70% alcohol-based sanitizer are still required, and protection such as wearing face masks, should be used when leaving the house. In addition, to increase the immunity and prevent from severe effect of COVID-19 disease, government should encourage community to vaccinated themselves in order to reduce the outbreak in our country. Thus, residents should be advised to take precautions to protect themselves from SARS-CoV-2 in the event of severe weather or in very polluted areas. Hopefully, the outcomes of this study would benefit policymakers in developing a better policy framework for Malaysia.

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