THE IMPACT OF COVID-19 PANDEMIC LOCKDOWN ON URBAN AIR QUALITY OBSERVATION FROM THE SENTINEL-5P TROPOMI OVER ISKANDAR MALAYSIA, JOHOR

Harris Aiman Najeeb

Supervisor:
Nurul Hazrina Idris

Faculty of Built Environment and Surveying
Universiti Teknologi Malaysia
2022

PSZ 19:16 (Pind. 1/13)

UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / UNDERGRADUATE PROJECT REPORT AND COPYRIGHT

Author's full name : HARRIS AIMAN NAJEEB

Date of Birth : 09/10/1996

Title : THE IMPACT OF COVID-19 PANDEMIC LOCKDOWN ON URBAN AIR QUALITY OBSERVATION FROM THE SENTINEL-5P TROPOMI OVER ISKANDAR MALAYSIA, JOHOR.

Academic Session : 2021/2022(2)

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
✓	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

1. I acknowledged that Universiti Teknologi Malaysia reserves the right as follows:
2. The thesis is the property of Universiti Teknologi Malaysia
3. The Library of Universiti Teknologi Malaysia has the right to make copies for the purpose of research only.
4. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

SIGNATURE OF STUDENT	**SIGNATURE OF SUPERVISOR**
B19BE0150	**Associate Prof. NURUL HAZRINA BINTI IDRIS**
MATRIC NUMBER	**NAME OF SUPERVISOR**
Date: 28 AUGUST 2022	Date: 28 AUGUST 2022

NOTES : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of the degree of Bachelor of Science (Geoinformatics)"

Signature	:	
Name of Supervisor	:	Associate Prof. Nurul Hazrina Binti Idris
Date	:	**28 AUGUST 2022**

THE IMPACT OF COVID-19 PANDEMIC LOCKDOWN ON
URBAN AIR QUALITY OBSERVATION FROM
THE SENTINEL-5P TROPOMI OVER
ISKANDAR MALAYSIA, JOHOR

HARRIS AIMAN NAJEEB

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Bachelor of Science (Geoinformatics)

Faculty of Built Environment and Surveying
Universiti Teknologi Malaysia

AUGUST 2022

DECLARATION

I declare that this thesis entitled *"The Impact of COVID-19 Pandemic Lockdown on Urban Air Quality Observation from The Sentinel-5P TROPOMI over Iskandar Malaysia, Johor"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	HARRIS AIMAN NAJEEB
Date	:	28 AUGUST 2022

DEDICATION

This thesis is dedicated to:

My Father and Mother. Their endless love, support, motivation, and taught me that the best kind of knowledge is learned for its own sake. (Najeeb Ab Rahman & Maziyah Yahya).

My supervisor. For providing me support, guidance, and counsel throughout this study (Associate Prof. Nurul Hazrina Idris).

Lastly, My Family, Love and Friend. For gave me the encouragement I need throughout the process of completing my study journey.

ACKNOWLEDGEMENT

In preparing this thesis, I contacted many people, researchers, and academicians. They have contributed to my understanding and thoughts. I express my sincere appreciation to my main thesis supervisor, Associate Prof. Nurul Hazrina Idris, for encouragement, guidance, criticism, and friendship. Without their continued support and interest, this thesis would not have been the same.

Then, I would like to express my gratefulness to my lovely family & friends. My sincere appreciation also extends to all my colleagues and others who have aided me on various occasions.

Finally, I would like to thank the Department of Environment Malaysia. Especially in the air department for providing the air quality data to make this study successful.

ABSTRACT

The COVID-19 pandemic is sweeping the globe, claiming hundreds of thousands of lives in just a few months. Because of the necessity of lockdown measures, most countries, including Malaysia, have enacted Movement Control Order (MCO) was effectively enforced on March 18, 2020, as a preventative measure to stem the disease's lethal spread. The concentrations of two criterion pollutions, Nitrogen Dioxide (NO_2) and Carbon Monoxide (CO) were measured at Iskandar Malaysia, Johor, before the lockdown from January 1 to March 17, 2020, during the lockdown from March 18 to December 31, 2020, and post lockdown from January 1 to December 31, 2021. The results demonstrate that NO_2 and CO concentration from COVID-19 lockdown did not decrease, especially during the movement control order phase, with an increment of 112% for NO_2 and 18% for CO. The primary causes of the air quality increase were that several sectors were closed during the MCO. Iskandar Malaysia was the industrial and economic sector for the southernmost point of Peninsular Malaysia, causing fossil fuel combustion, power plant, local burning activities, and home appliances. The increment did not solely depend on MCO; maybe there is another reason for that increment. This study is to understand the COVID-19 lockdown affecting the urban air quality in Iskandar Malaysia before, during, and post-COVID-19 pandemic lockdown.

ABSTRAK

Penyebaran virus COVID-19 berskala pendemic, kini meragut ratusan ribu nyawa dalam beberapa bulan sahaja. Disebabkan penyebaran melalui udara, keperluan langkah berkurung telah dikuatkuasakan bagi setiap negara dan Malaysia antara salah satunya. Dimana telah menggubal Perintah Kawalan Pergerakan (PKP) mulai Mac 18, 2020, sebagai langkah pencegahan untuk membendung penularan virus COVID-19. Terdapat dua ciri-ciri kepekatan pencemaran udara, iaitu *Nitrogen Dioxide* (NO_2), dan *Carbon Monoxide* (CO) telah terukur di Iskandar Malaysia, Johor, sebelum sekatan pergerakan bermula pada Januari 1 sehingga Mac 17, 2020, semasa sekatan pergerakan bermula pada Mac 18, sehingga Disember 31, 2020, dan pasca sekatan pergerakan bermula pada Januari 1 sehingga Disember 31, 2021. Keputusan daripda kajian ini, menunjukkan yang kepekatan NO_2, dan CO daripada perintah berkurung COVID-19 adalah tidak berkurang, terutamanya semasa fasa perintah kawalan pergerakan, dengan kenaikan sebanyak +112% untuk NO_2 and +18% untuk CO. Punca utama perkara ini berlaku kerana tidak semua sektor ditutup semasa perintah kawalan pergerakan. Iskandar Malaysia dikenali sebagai sektor perindustrian dan ekonomi untuk kawasan paling selatan Semenanjung Malaysia, menyebabkan pembakaran bahan api fosil, loji kuasa, aktivit pembakaran tempatan dan peralatan rumah. Kenaikan pencemaran udara ini tidak semata-mata bergantung pada perintah kawalan pergerakan; mungkin ada sebab lain untuk kenaikan itu. Kajian ini adalah untuk memahami kualiti udara bandar dalam situasi keadaan perintah berkurung disebabkan oleh virus COVID-19 di Iskandar Malaysia bagi keadaan sebelum, semasa, dan selepas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IM	-	Iskandar Malaysia
Sentinel-5P	-	Sentinel-5 Precursor
TROPOMI	-	TROPOspheric Monitoring Instrument
NO_2	-	Nitrogen Dioxide
CO	-	Carbon Monoxide
DOE	-	Department of Environment Malaysia
MCO	-	Movement Control Order
COVID-19	-	Coronavirus Disease 2019

LIST OF SYMBOLS

μ	-	Micro

LIST OF APPENDICES

APPENDIX	TITLE	PAGE

No table of figures entries found.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Anthropogenic air pollutants are a source of concern for human health, particularly in the metropolitan area where economic activity and fast industrialisation relate to poor air quality. Studies on air pollution and human health have been conducted to investigate the harmful effects of air pollution on human health, DNA damage, reduced lung function, preterm delivery for pregnant women, and cardiopulmonary disease (Othman & Latif, 2021). One of the most significant environmental challenges facing our society is the threat posed by climate change. One of the leading greenhouse gases is carbon monoxide (CO). Fossil fuel burning, deforestation, unsustainable biomass combustion, and the release of mineral source of CO are all example of anthropogenic sources of CO (Worrell et al., 2001). Same goes for nitrogen dioxide (NO_2), which is predominantly released as a by-product of combustion and participates in the creation and decomposition of ozone (O_3), is a major factor in determining the quality of the air in metropolitan areas (Dunlea et al., 2007). Since Malaysia has become more urban and industrialised in recent years, air pollution has become a severe environmental concern (Kanniah et al., 2021). The main contributors to air pollution come from stationary (industries and power plant) as well as mobile (road motor vehicle, aeroplanes, and trains) (Usmani et al., 2020).

The respiratory condition has had a significant impact on one's health. The SARS-CoV-2 (COVID-19) coronavirus impacted practically every country; the disease is classified as a pandemic due to its global impact. COVID-19 was discovered near Wuhan, China, in December 2019. There were over 18 million new cases instances of COVID-19 in the world as of January 10 - 16, 2022, with a 20 per cent increase compared to the previous week (WHO, 2022b). SARS-CoV-2, which affects the lower respiratory system and operates similarly to pneumonia, was the original cause of the pandemic (Othman & Latif, 2021). Phase 1, 2, and 3 of the COVID-19 control technique were implemented in Malaysia beginning on March 18, 2020, under the name movement control order (MCO) (Mohd Nadzir et al., 2020). Except for a few crucial industries, the MCO prohibits all government sectors and commercial activity in Malaysia. Universities, schools, day-care centres, and commercial centres are prohibited from holding educational activities.

Additionally, mass gatherings are outlawed, and travel and leisure time are limited. According to a study on COVID-19 control methods in China, the epidemic scale was successfully reduced after the control measure were implemented. This suggest that careful monitoring and early case detection of COVID-19 cases should continue until the end of April 2020 (Othman & Latif, 2021).

Iskandar Malaysia (IM) is a ten-year-old spatial and economic development framework for envisioned economic expansion, which includes a redefinition for a more extensive spatial urban configuration that incorporates Johor Bahru's core urban centre. IM has evolved into a critical role in Malaysia's economic development in recent years. IM's new geographical framework, as outlined in the Iskandar Comprehensive Development Plan (Rizzo & Glasson, 2012), has been marked by a well-planned urban sprawl fueled by substantial international and local investment (Zahari et al., 2016).

1.2 Problem Background

COVID-19 was first reported in Malaysia on January 24, 2020. The WHO (World Health Organization) Country Office in Malaysia has coordinated response efforts with the Ministry of Health (WHO, 2021a). The Malaysian government proclaimed a state of a public health emergency. A series of swift and severe responses have been implemented, including the isolation of cities and the first Movement Control Order (MCO) implementation effective on March 18 till May 03, 2020 (BH Online, 2021).

As the effect of implementing an MCO, all the economic sectors were shutting down, no universities and schools were allowed, and shopping malls were also asked to close. Somehow, it gave scientists some space to study the effect of COVID-19 on the environment, especially in urban air quality monitoring. According to Hashim et al. (2021), Shows a positive result in NO_2 column observations during COVID-19 pandemics in countries like Spain, India, Brazil, and China. The use of S-5P/TROPOMI resulted in a considerable reduction in the proportion of NO_2 in India and China, with 70 per cent and 20-30 per cent reduction in NO_2 in India and China, respectively. In European countries, NO_2 levels were reduced by 20-30 per cent (i.e., Spain, Italy, and France).

Since the population increases worldwide, the air pollutants are the main contribute to economic development, urbanisation, energy consumption, transportation, and motorisations (Kaplan et al., 2019). In Malaysia, the population estimate in 2021 at 32.7 million compared to 2020 at 32.6 million with an annual growth rate of 0.2 per cent (DOSM, 2021). The post-COVID-19 air quality index (AQI) for December 03, 2021, in Klang, Selangor and Johor Bahru, with 75 and 60 AQI (Moderate), respectively (WAQI, 2021). In this study, we want to see the COVID-19 pandemics lockdown footprint on urban air quality through the eye of satellite Sentinel-5P/TROPOMI as nitrogen dioxide, and carbon monoxide is the subject towards Iskandar Malaysia, Johor Bahru.

1.3 Significant of the study

The significance of the study is that it could compare the urban air quality through COVID-19 pandemic lockdown by phase in pre, during, and post in the Iskandar Malaysia region. Further, this study also compares the five (5) flagships zones that were recognise by Iskandar Regional Development Agency (IRDA) as shown in Figure 1 to assess the air quality of nitrogen dioxide and carbon monoxide in pre, during, and post COVID-19 lockdown. Hence, this study would be beneficial to the local authorities and researcher in future in enhancing the sustainable cities around Iskandar Malaysia. As IRDA states that Iskandar Malaysia aims to reduce greenhouse gas emissions to 50% by 2025 (IRDA, 2013).

All living things rely on clean and safe air to survive, so it is critical to maintain it clean and safe. Anthropogenic activities are a primary source of ambient air pollution, as they emit a variety of hazardous pollutants in high concentrations that are injurious to one's health. As a result, economic development, urbanisation, energy consumption, transportation, and rapid urban population growth are the primary sources of air pollution. Particulate matter (PM), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), Ozone (O_3), carbon monoxide (CO), and carbon dioxide (CO_2) are the most common air pollutants we face in our daily life (Hashim et al., 2021).

1.4 Research Aim and Objectives

This study aims to assess the air quality in pre, during, and post COVID-19 pandemic lockdown over Iskandar Malaysia, Johor, using the Sentinel-5P/TROPOMI satellite.

The objective is:

1. to apply the Sentinel-5P/TROPOMI satellite data product and ground station data in accessing the nitrogen dioxide and carbon monoxide.
2. to validate the satellite data product using secondary data.
3. to map and analyse the air quality changes in pre, during, and post of COVID-19 pandemic lockdown over Iskandar Malaysia region.

1.5 Research Question

In order to fulfill the objectives, three (3) research questions have been developed. The research question is:

1. what are the air quality parameters could be retrieved from Sentinel-5P/TROPOMI?
2. what is the accuracy assessment for Sentinel-5P data product with ground station data?
3. what is the impact of COVID-19 lockdown towards the air quality?

1.6 Research Scope

This study focusing on the urban air quality in Iskandar Malaysia (IM) in pre, during, and post COVID-19 pandemic outbreaks by accounting NO_2, and CO in producing map from Sentinel-5P/TROPOMI. The timeframe for whole study starts from January 2020 (before total lockdown in Malaysia March 18) – December 2021 (in post-COVID-19 period). The data product Level 2 (L2) of NO_2, and CO were obtain from The European Space Agency (ESA). In addition, for accuracy assessment, both parameters were obtained from The Department of Environment Malaysia (DOE). For result and analysis part, the air pollution concentrations analysis, the air quality changes, root mean square error and correlation coefficient analysis will be conducted thus, the air quality concentration map produced.

1.7 Study Area

Johor Bahru, the capital of Johor State in Malaysia, is a city of 500,000 people located at the peninsula's southern tip; the larger JB metropolitan area had a population of about 1.3 million in 2006 (Rizzo & Glasson, 2012). After Kuala Lumpur's capital, Johor Bahru is Malaysia's second-largest metropolitan area. Nearly every big industrial brand has a branch in the Johor Bahru metropolitan area, which is a hub for business and industry. Schematically, electronic, and semi-conductor factories are located near the Senai area, the airport, and some are close to the Port Tanjung Pelepas cargo harbour, in the new tax-free zone, while small and medium-sized businesses are dispersed throughout the city. Pasir Gudang is the main petrochemical harbour and is located to the east of the Johor Bahru agglomeration (IRDA, 2013).

Iskandar Malaysia, Figure 1, formed in 2006, is Malaysia's first economic area. It leverages the country's rich location and ecology to achieve its aim of being the chosen place for investment, work, life, and play. Iskandar Malaysia has become vital in Malaysia's economic development in recent years. Iskandar Malaysia's new geographical framework, as outlined in the Iskandar Comprehensive Development

Plan (Zahari et al., 2016), has been marked by a well-planned urban sprawl fueled by substantial international and local investments in the commercial, institutional, and industrial sectors, resulting in strong economic growth. It is ideal situated at a key intersection of East-West trade routes from quickly developing nations like China and India. Regionally, the growth of Iskandar Malaysia gives a stronger competitive edge and greatly profit form the air and sea connections among the Asia-Pacific nations.

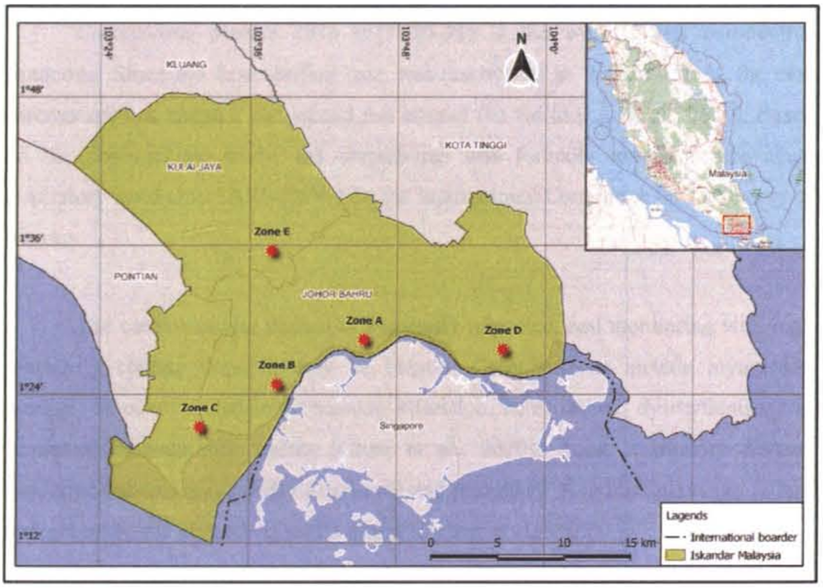


Figure 1 The map of Iskandar Malaysia, Johor, which consists of five (5) flagship zones.

Iskandar Malaysia consists of five (5) flagship zones. These flagship zones all have significant urban centres. Zone A: Johor Bahru City, Zone B: Planned Nusajaya urban centre. Zone C: Western Gate Development, Zone D: Eastern Gate Development, and Zone E: Senai-Skudai (Ho et al., 2013).

CHAPTER 2

LITERATURE REVIEW

2.1 Brief Introduction into Pandemic COVID-19 virus

Coronavirus disease 2019 (COVID-19) is the world's first coronavirus pandemic. Since the first verified case was discovered in Wuhan, China, the new coronavirus has mutated and spread fast around the world (Liu et al., 2020). Based on the phylogenetic study, the coronavirus was formally termed severe acute respiratory syndrome SARS-CoV-2 by the International Committee on Taxonomy of Viruses.

The cardiovascular system is frequently impacted, and monitoring with high sensitivity cardiac troponin may be helpful. Complications include myocardial damage, myocarditis, acute myocardial infarction, heart failure, dysrhythmias, and venous thromboembolic events (Ciotti et al., 2020). Acute respiratory distress syndrome patients may rapidly deteriorate and pass away from multiple organ failure brought on by the alleged "cytokine storm" (Wang et al., 2020).

Patients infected with SARS-CoV-2 may exhibit various symptoms ranging from mild to severe. Fever, cough, and shortness of breath are the most often reported symptoms in 83%, 82%, and 31% of patients, respectively (Wang et al., 2020). It has also been observed that 2-10 per cent of COVID-19 patients experienced gastrointestinal symptoms such as vomiting, diarrhoea, and abdominal discomfort (Wang et al., 2020).

2.1.1 Movement Control Order (MCO) in Malaysia

MCO refers to the lockdown or total restriction of mass movements and meetings, including religious, sporting, social, and cultural activities. It entails closing all government and private establishments to save those engaged in critical activities, imposing comprehensive limitations on all Malaysian travelling overseas, and imposing restrictions on international tourists and visitors (Baharudin et al., 2021). Table 1 shows the chronology of the Movement Control Order (MCO), Conditional Movement Control Order (CMCO), Recovery Movement Control Order (RMCO), and National Recovery Plan in Johor.

Table 1
Phase in Movement Control Order in Malaysia and Johor states were include from January 11 – December 31, 2021 (MKN, 2022).

Phase	Period
Movement Control Order (MCO, March 18, 2020 – May 3, 2020)	
Phase 1	March 18 – March 31
	April 1- April 14
	April 15 – April 28
	April 29 – May 3
Conditional Movement Control Order (CMCO, May 4, 2020 – June 9, 2020)	
Phase 2	May 4 – May 12
	May 12 - June 9
Recovery Movement Control Order (RMCO, June 10, 2020 – March 31, 2021	
Phase 3	June 10 – August 31
	September 1 – December 31
	January 1 – March 31
Movement Control Order by States (January 11 – May 31, 2021)	
MCO Phase 1	January 13 – January 26
MCO Phase 2	January 26 – February 4
MCO Phase 3	February 4 – February 16
MCO Phase 4	February 16 – March 4
CMCO	March 4 – March 12
CMCO	March 13 – April 28
MCO Phase 5	May 7 – May 20
National Recovery Plan (NRP, June 15, 2021 – December 31, 2021)	
Phase 1	June 1 – October 1
Phase 2	September 24 – October 8
Phase 3	October 8 – October 25
Phase 4	October 25 – until further notice

Table 2
Simplest phase of movement control order in Malaysia.

Phase	Period
Before MCO	January 01 – March 17, 2020
During MCO	March 18 – December 31, 2020
Post MCO	January 01 – December 31, 2021

Table 2 shows the rough chronology of the movement control order in Malaysia. Such movements increased the risk of COVID-19 spread, which was connected to the rise in daily COVID-19 cases over the following 14 days, peaking on March 26, 2020 (Tang, 2022). The lockdown or total restriction of mass movements and meetings, such as religious, sports, social, and cultural activities, is referred to as MCO (Baharudin et al., 2021).

2.2 Brief Introduction into Sentinel-5P TROPOMI

Between 2017 and at least 2023, the Sentinel-5P (P for precursor) mission will provide information and services on air quality and climate as shown in Table 3 (Sentinelhub, 2022). The Sentinel-5 Precursor satellite, carrying the Tropospheric Monitoring Instrument (TROPOMI) as its single payload, was successfully launched on October 13, 2017 (ESA, 2022). It makes daily worldwide observations of major atmospheric elements such as ozone, nitrogen dioxide, Sulphur dioxide, carbon monoxide, methane, formaldehyde, cloud, and aerosol characteristics with the TROPOMI sensor on board.

TROPOMI is a next-generation atmospheric sounding instrument that builds on the triumphs of GOME, SCIAMACHY, OMI, and OMPS by providing better spatial resolution, increased sensitivity, and a wider wavelength range. The device has four spectrometers separated into two modules that share a single telescope and measure the Earth's ultraviolet, visible, near-infrared, and shortwave infrared reflectance. The imaging system provides daily worldwide coverage with a push-broom configuration and a spatial resolution 5.6* km x 3.5 km in nadir from an 824 km Sun-synchronous orbit with an Equator crossing time of 13:30 local solar time (Kleipool et al., 2018).

Table 3
Basic info of Satellite Sentinel-5P TROPOMI.

Property	Info
Spatial resolution	Up to 5.6* km x 3.5 km.
Sensor	Tropospheric Monitoring Instrument (TROPOMI), a spectrometer measuring ultraviolet and visible (270-495 nm), near infrared (675-775 nm), and shortwave infrared (2305-2385 nm) light.
Revisit time	Less than one day.
Spatial coverage	Global coverage.
Data availability	Since April 2018
Common usage/purpose	To provide global information on a multitude of atmospheric trace gases, aerosols and cloud distributions affecting air quality and climate.

Adapted from: (Sentinelhub, 2022)

2.3 Brief Introduction into Urban Air Quality

The term "urban air quality" refers to how "clean" the air is inside cities with a density, population, and level of activity that are commonly considered "urban." In general, urban air quality differs from rural air quality because there are more concentrated sources and the capacity of contaminants in the air to disperse is limited by physical limits in the urban environment. Because of differences in pollution control and the usage of open fires in urban areas, urban air quality differs dramatically in urban cities in industrialised and non-industrialised worlds.

Nonetheless, air pollution is still blamed for illness, deaths, and environmental harm all around the world (WHO, 2022a). Every year, an estimated seven million people die as a result of air pollution. According to WHO data, almost all of the world's population (99 %) breathes air that exceeds WHO guideline limits and contains high levels of pollutants, with low- and middle-income countries suffering the most (WHO, 2022a).

2.3.1 Nitrogen Dioxide (NO_2)

Nitrogen Dioxide (NO_2) is a highly reactive gas that belongs to a larger group of gases called nitrogen oxides (NO_x) (Prunet et al., 2020). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 serves to indicate the larger group of nitrogen oxides. The way NO_2 enters the air is mainly by burning fuel from emissions from cars, trucks, buses, power plants, and off-road equipment.

Breathing in air with high concentrations of NO_2 can irritate the human respiratory tract. Such short-term exposure can aggravate respiratory diseases, especially asthma, and lead to respiratory symptoms such as coughing, wheezing or difficulty breathing. Besides affecting humans, NO_2 can penetrate the environment with water, oxygen, and other chemicals in the atmosphere to form acid rain. The abbreviation NO_2 refers to a bigger range of nitrogen oxides, NO_2 enters the atmosphere primarily from the combustion of fuel from automobiles, trucks, buses, power plants, and off-road equipment. A recent study from the cities of Madrid and Barcelona found that traffic is responsible for 65% of the NO_2 emissions (Săvulescu et al., 2020), while the remaining 35% comes from other sources, such as the industrial sector, activity at power plants, and heating.

2.3.2 Carbon Monoxide (CO)

CO is a colourless, odourless gas that, when inhaled in excessive volume, can be dangerous. When anything is burned, CO is released. Cars, trucks, and other fossil-fuel-burning vehicles and machinery are the most significant emitters of CO in the outdoor air (EPA, 2021). CO is a pollutant that is crucial for the chemistry of the atmosphere, including the production of tropospheric ozone (Minqiang et al., 2021).

Breathing CO-rich air limits, the quantity of oxygen that can be transferred to vital organs like the heart and brain through the bloodstream. CO can cause dizziness, confusion, unconsciousness, and death at very high levels, which are possible indoors or in other confined places (WHO, 2021b). When compared to other air contaminants, CO has a relatively lengthy lifetime (week to months), and OH is primarily responsible for removing it (Aschi & Largo, 2003).

2.4 Data Accuracy

2.4.1 Sentinel-5P Data Product (L2)

The TROPOMI multi-spectrometer exceeds comparable systems by a factor of 100, with a spatial resolution of 3.5 kilometre by 7 kilometres (ESA, 2022). Air pollution from cities and build-up areas may now be detected from space for the first time. With complimentary orbits, the satellite orbits Earth 14 times every day. Individual data products, whether they relate to nitrogen dioxide concentrations or sulphur dioxide concentrations, are made accessible within three hours of the observations being taken. Sentinel-5P, overall, provides a daily global dataset for atmospheric composition

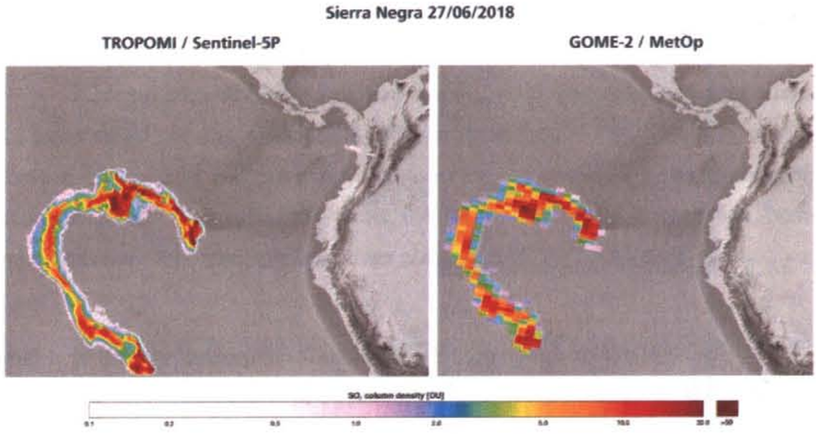


Figure 2 On June 27, 2018, the image depicts the propagation of the sulphur dioxide cloud from the Sierra Negra volcano. On the left, the TROPOMI / Sentinel-5P measurement result, and on the right, the EUMETSAT MetOp-A and MetOp-B satellite measurements. The image is made up of DLR / BIRA-processed Copernicus Sentinel data (2018) (DLR, 2018).

The Sentinel-5P mission is unique due to the complex technical processes required to produce a total of 12 end products with a daily data volume of up to two terabytes. The raw spectral data from the TROPOMI measurements are received by the ground station in the Arctic and transmitted to DLR via global fibre-optic links, following a highly complex processing chain (DLR, 2018). They are then analysed, filtered, and processed into individual data products (L2) before being made available on a web server automatically.

2.5 Previous Research

2.5.1 Based on Remote Sensing, Air Quality, and COVID-19

In Malaysia, there is study done by Kanniah et al. (2020) to investigate of MCO / lockdown measures on air quality in the South East Asia (SEA) region using satellite remote sensing (Himawari-8) and ground-based measurements with special focus on Malaysia. The method they are using to assess is aerosol optical depth (AOD) data product level 3 (L3) from Himawari-8 with a spatial resolution of 5km, and data of air pollution from DOE, Malaysia. The findings from the study shows, seasonal biomass burning has no effect on Himawari-8 AOD reduction in urban areas. During the lockdown phase, reduction in $PM_{10}, PM_{2.5}, NO_2, SO_2, and\ CO$ are 26%, 23 - 32%, 63 – 64%, 9 – 20%, and 25 – 31%, respectively, in urban areas. The study shows, COVID-19 lockdown can reduce the trends in aerosols and air pollutants in SEA especially in Malaysia the moderate industrial development country.

The second study by Ghahremanloo et al. (2021), in examine the influence of the COVID-19 epidemic and associated quarantines on East Asia's lowering pollutants levels showing that, the NO_2 experienced the highest decrease in East Asia due to lockdowns, NO_2 (83%) and SO_2 (71%) decreased more than $HCHO$ (11%) and CO (4%) in Wuhan, and SO_2 increased in Seoul and Tokyo due to polluted air transport in 2020. The researcher investigated $NO_2, HCHO, SO_2, and\ CO$ concentrations as well as the aerosol optical depth (AOD) over the BTH, Wuhan, Seoul, and Tokyo regions in February 2019 and February 2020 using data from the Sentinel-5P and Himawari-8 satellites. In conclusion, the study show mostly reduction in every air pollution concentration except carbon monoxide with dramatically reduction because of as the temperature rose, more biogenic VOC emissions were oxidized, resulting in higher amounts of HCHO and CO.

2.5.2 Based on Air Pollution and COVID-19

In article Air pollution impacts from COVID-19 pandemic control strategies in Malaysia by Othman and Latif (2021) goal is to investigate the potential changes in concentrations of air pollutants caused by MCO in nine major cities in Malaysia. The method they are using were air pollution data collection from DOE, air mass trajectories (Hybrid Single-Particle Lagrangian Integrated Trajectory), statistical analysis (t-test, and one-way ANOVA), and health risk assessment. From the research findings, the largest reduction of $PM_{2.5}, PM_{10}, SO_2, O_3, and\ CO$ were recorded at Kota Kinabalu, Kuantan, Alor Star, Kota Bahru, and Ipoh, 17%, 9.5%, 38%, 15%, and 27%, respectively. And an average hazard index (HI) value of 1.44E-01 (before the MCO) and 1.40E-01 (during the MCO) showed higher human health risks before the MCO than during the MCO.

Next article from Abdullah et al. (2020) on air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic. The study is to evaluate the variation of $PM_{2.5}$ changes during and before MCO in Malaysia. The method that was using is acquiring the air pollutant index (API) data from the Department of Environment Malaysia on an hourly basis before and during the MCO on $PM_{2.5}$ concentration at 68 air quality monitoring stations. From the research findings, the $PM_{2.5}$ concentrations dominated the Air Pollutant Index (API) in Malaysia, several decreases in $PM_{2.5}$ values occurred under the Malaysia Movement Control Order (MCO), $PM_{2.5}$ concentrations were reduced by roughly 28.3% in certain red zone regions., and with a 23.7% average reduction in $PM_{2.5}$ concentrations, the Northern Region of Peninsular Malaysia had the largest average reduction. It may be concluded that the MCO has a major impact on lowering $PM_{2.5}$ concentrations in Malaysia. It should be highlighted that additional elements like as weather, traffic density, industrial activity, and biomass burning should be investigated further.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction on Methodology

The methodology of this study can be divided into four stages. The first stage is data acquisition, the second stage is data pre-processing, the third stage is data processing, and the fourth stage is results and analysis as shown in Figure 3. In the data acquisition, the data is divided into 2 categories. The first data is primary data which come from the Sentinel-5P/TROPOMI satellite data product (L2). The second data is secondary data which obtain from DOE. In data pre-processing stage, both data from primary and secondary will go through the data quality process, then moving on to subset the satellite Sentinel-5P data product according to the study area in Figure 1.

Furthermore, in data processing. The accuracy assessment is being carried out to determine the accuracy of the satellite Sentinel-5P data product with the in-situ data (Secondary data). Secondly, the daily data product was averaged phase three (3) phase (before, during, and after MCO), and continued with calculation and generating map. Lastly in result and analysis, the calculated data were analysed and compared to come out with the discussion. Figure 3 illustrates the methodology involve for the whole process in seeing the impact of COVID-19 pandemic lockdown on urban air quality in Iskandar Malaysia.

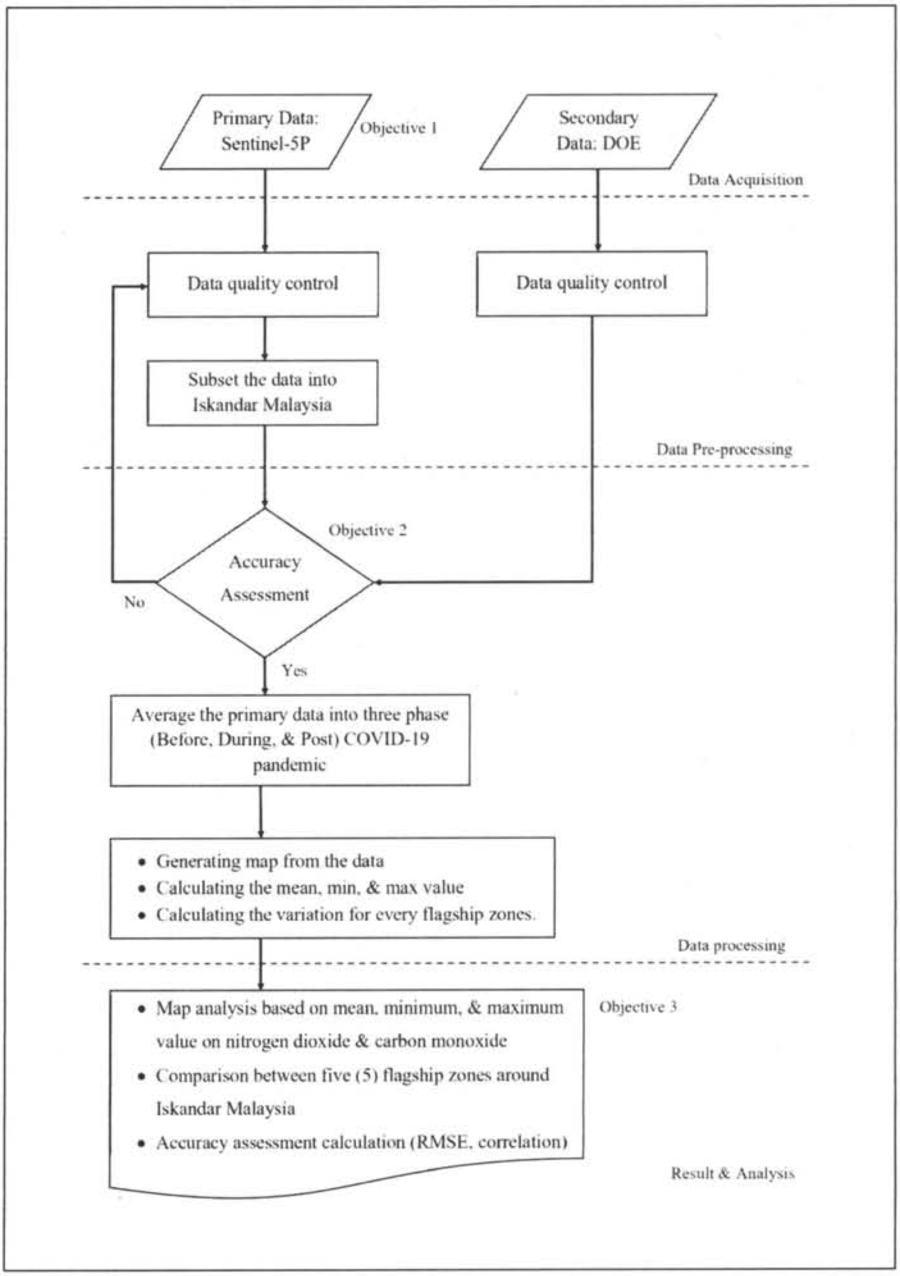


Figure 3 Flowchart of methodology.

3.2 Data Acquisition

3.2.1 Sentinel 5P / TROPOMI Data Product (L2)

TROPOMI data products is use as a primary data in this study which were obtain from The European Space Agency (Open Access Hub (copernicus.eu)). We make use of data collected by the push-broom imaging spectrometer TROPOMI, an S5P instrument (Levelt et al., 2021). Atmospheric concentrations of various gases, as well as cloud and aerosol features, are recovered using the spectral radiance data from TROPOMI. We utilise the following TROPOMI data products for our works: NO2 and CO.

The Table 4 below lists the TROPOMI Level 2 data package generated by the Copernicus ground system. There are three types of data streams: near-real-time (NRTI), non-time critical or offline (OFFL), and reprocessing (RPRO) (TROPOMI, 2022). In this study, the offline data were selected with using nitrogen dioxide, and carbon monoxide data product.

Table 4
List of S5P/TROPOMI Level 2 Data Products

Product	Main Parameter	Data file descriptor	Developers
UV Aerosol Index	Aerosol index	AER_AI	KNMI
Aerosol Layer Height	Mid-level pressure	AER_LH	KNMI
Carbon monoxide (CO)	Total column	CO___	SRON
Cloud	Fraction, albedo, top pressure	CLOUD_	DLR
Formaldehyde (HCHO)	Total column	HCHO__	BIRA-IASB
Methane (CH_4)	Total column	CH4___	SRON
Nitrogen dioxide (NO_2)	Tropospheric column	NO2___	KNMI
Ozone profiles	Total and tropospheric profiles	O3_PR_	KNMI
Sulphur dioxide (SO_2)	Total column	SO2___	BIRA-IASB
Ozone (O_3)	Total column	O3___	DLR
Tropospheric Ozone (O_3)	Tropospheric column	O3_TCL	DLR
UV[1]	Surface irradiance erythemal dose	_____	FMI

* Bold data product indicates the selected data for this study.

3.2.2 Ground Monitoring Station

The Department of Environment (DEO), part of the Ministry of Environment and Water, is responsible for managing the air quality in Malaysia. The data from DOE were used as our secondary data for the S5P accuracy assessment. The air pollutions parameters obtained from DOE were also the same as those obtained from S5P satellites (NO_2, and CO), where the location of the data was collected from the ground station at Larkin, Johor (S33: Lat:1.495, Lon: 103.736), and Pasir Gudang, Johor (S34: Lat: 1.470, Lon: 103.894).

3.3 Data Pre-Processing & Data Processing

Upon completion of data acquisition, the subsequent phase is data processing. Raw data were filtered by using SNAP Desktop software, where this process eliminated the missing data (70% loss) obtained from S5P. Then the data undergoes reprojection into the WGS84 Datum as shown in Figure 4, followed by a subset process focusing around Iskandar Malaysia. We then extracted NO_2 and CO from raw data by using MATLAB software.

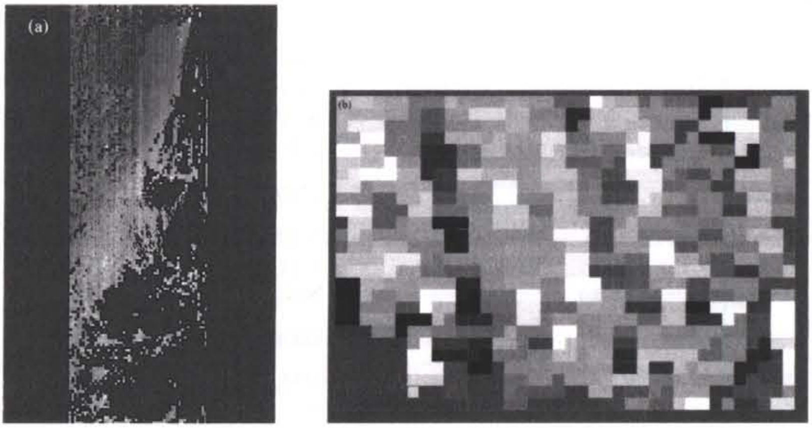


Figure 4 (a) Example of before reprojection, (b) Example of after reprojection and subset.

Once the data were ready, we moved into the data processing procedure, where the first thing was to validate the TROPOMI data with ground station data by using root mean square error (RMSE) and correlation coefficient (r^2) calculation that will discuss in Chapter 3.4. After the satellite data meet the requirement, we then average all data into three (3) phases, which were before (Jan – Mar 2020), during (Mar – Dec 2020), & post (Jan – Dec 2021) COVID-19 pandemic. Later, the average data were gone through generating a map for each concentration, and several calculations such as finding the mean, minimum, and maximum value, the variation for every five (5) flagship zones.

3.4 Accuracy Assessment

As using Sentinel-5P data product, validation through ground-based secondary data will acquire the best differentiation between both sensors. Since it is impossible to directly count the number of molecules across vast areas, validating NO_2 and CO concentration estimations from S5P in the tropospheric is a difficult issue. It can be contrasted with other estimations from other ground-based equipment that have been shown to produce good fits and have undergone the validation process. Thus, we normalise both concentration data before apply the accuracy assessment, in changing the values of numeric columns in the dataset to a common scale, without distorting differences in the ranges of values.

The average error or uncertainty of the model is defined by the RMSE equation (1). The quantities being compared and the units of RMSE are the same. It is advised that the model inputs and verification be reviewed in order to make changes if the RMSE values are greater than 25% of the target being evaluated (Scotland). Where satellite data (x_i) represent the actual observation time series and the ground data ($\hat{x}_i$) represent estimated time series. N is the number of non-missing data points.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}{N}} \quad (1)$$

The correlation coefficient is to estimate the effect of some explanatory variable on the dependent variable. Below is the formula for correlation coefficient that will use to validate the Sentinel-5P data product with data obtain from DOE. Where; r^2: correlation coefficient, x_i is values of the x-variable in a sample, $\bar{x}$ is mean of the values of the x-variable, y_i is values of the y-variable in a sample, and $\bar{y}$ is mean of the values of the y-variable.

$$r^2 = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (2)$$

CHAPTER 4

RESULTS AND DISCUSSION

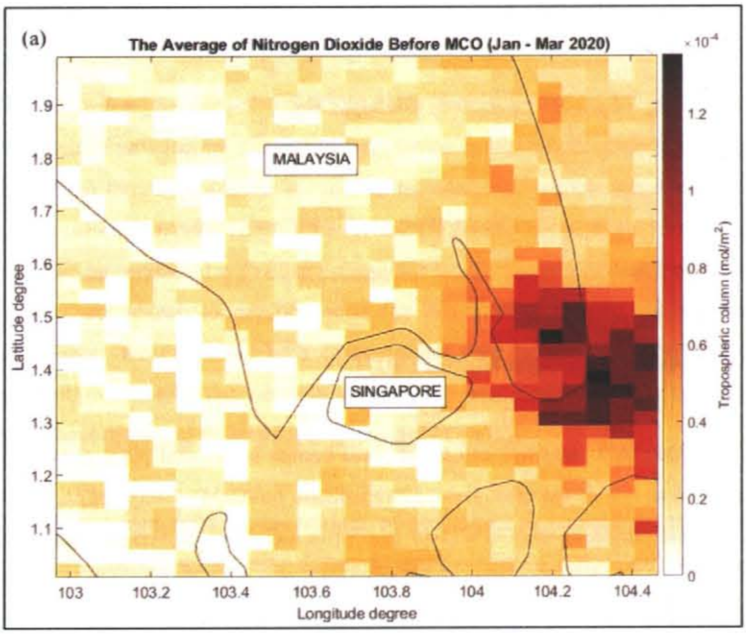
4.1 Average Nitrogen Dioxide (NO_2)

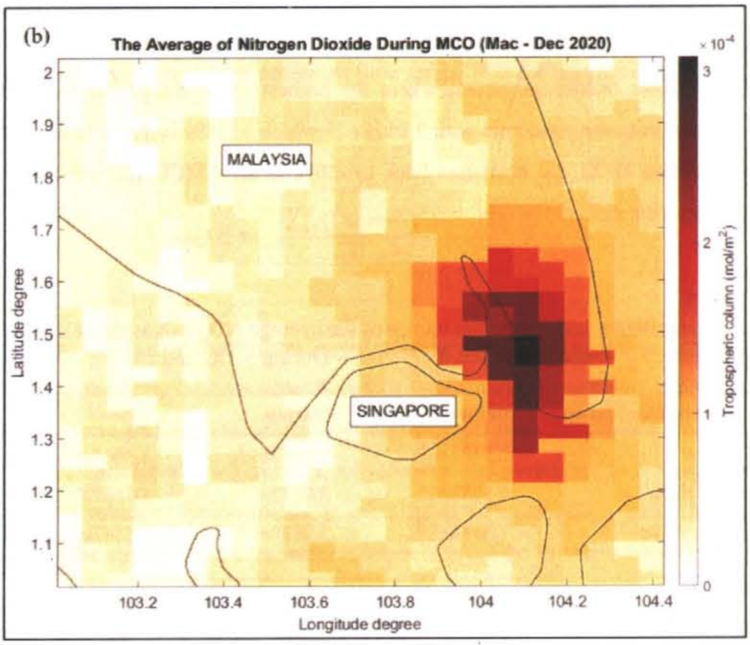
Due to its negative effects on both human health and plant growth, NO_2 is regarded as one of the most serious atmospheric pollutants (Metya et al., 2020). For the whole period of the COVID-19 pandemic lockdown around Iskandar Malaysia showed an increase in NO_2 concentrations obtained from satellite images as displayed in Figure 5, especially in Pasir Gudang, Johor. The average concentration of mean difference for NO_2 increase +112% (before – during MCO), while the reduction only occurs for during – after MCO with -39% as shown in Table 5. Table 5 also shows maximum values, where the highest value among the three periods were in during the pandemic with $3.0828e^{-4}$ which +128% increase in air pollution from before MCO and decreases back to -50% in after MCO (during the national recovery plan in 2021).

Table 5
Mean, minimum, and maximum values of the average $\mathbf{NO_2}$ tropospheric column calculated. The mean difference for Before – During MCO and During – After MCO.

Descriptive Statistics	Before	During	After
Mean	$2.5403e^{-5}$	$5.3872e^{-5}$	$3.3017e^{-5}$
Min value	$3.5082e^{-6}$	$3.9330e^{-6}$	$3.7667e^{-7}$
Max value	$1.3544e^{-4}$	$3.0828e^{-4}$	$1.5547e^{-4}$

	Before – During	During - After
Mean difference (%)	+112	-39


(a)
The Average of Nitrogen Dioxide Before MCO (Jan - Mar 2020)
MALAYSIA
SINGAPORE
Latitude degree
Longitude degree
Tropospheric column (mol/m²)
× 10⁻⁴


(b)
The Average of Nitrogen Dioxide During MCO (Mac - Dec 2020)
MALAYSIA
SINGAPORE
Latitude degree
Longitude degree
Tropospheric column (mol/m²)
× 10⁻⁴

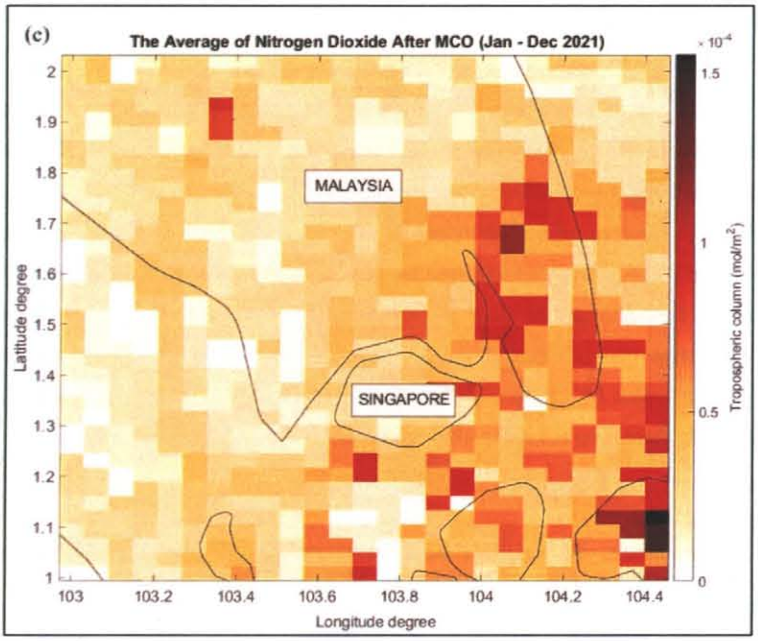


Figure 5 The average nitrogen dioxide concentration map around Iskandar Malaysia, where: (a) Before MCO; (b) During MCO; and (c) After MCO.

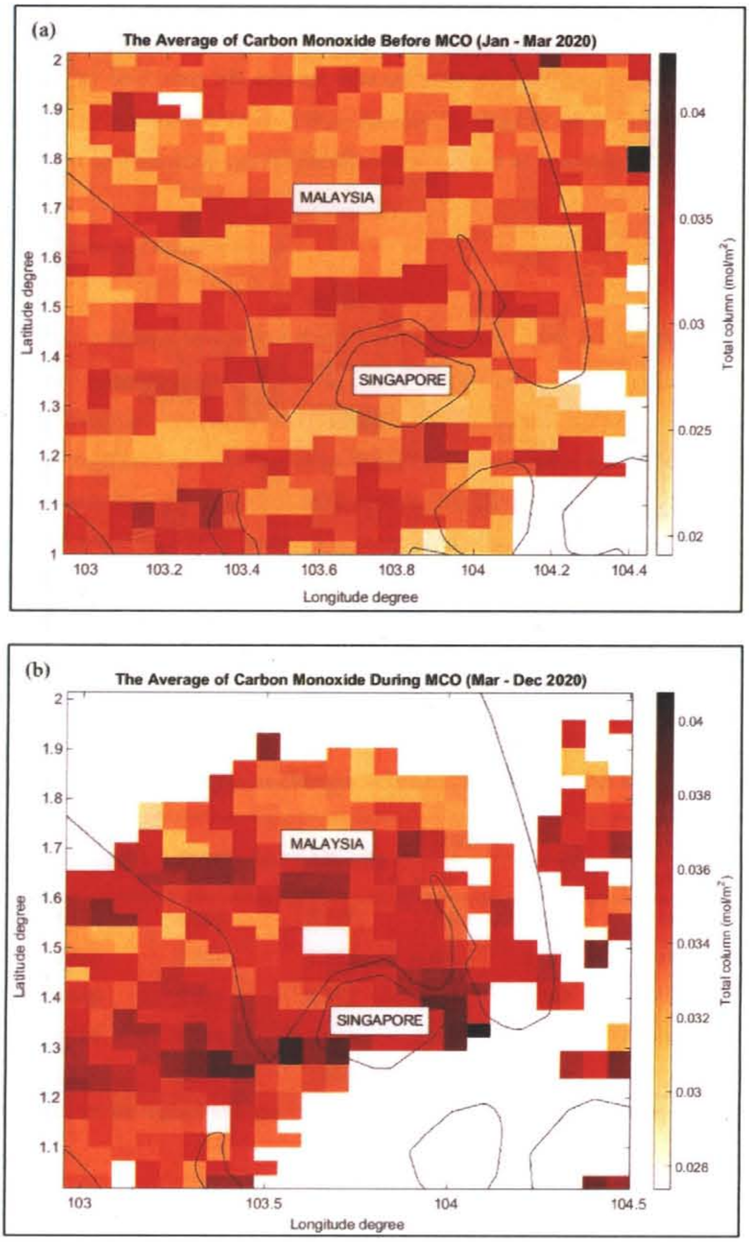
4.2 Average Carbon Monoxide (CO)

Automobiles, lorries, and airplanes are major contributors to incomplete combustion, which contributes to the atmospheric concentration of CO. Burning gases and wood are additional crucial sources (Ghahremanloo et al., 2021). Figure 6 shows the increase of carbon monoxide after the pandemic period with a maximum value of 0.0465 compared to before the pandemic with 0.0428, and a slight reduction of -5% during the pandemic as shown in Table 6. For the whole picture of average carbon monoxide concentration, the value of mean difference before and during MCO increases by +18%, and slightly the growth of +1% during and after MCO. Showing there is no reduction after the MCO.

Table 6
Mean, minimum, and maximum values of the average **CO** total column calculated. The mean difference for Before – During MCO and During – After MCO.

Descriptive Statistics	Before	During	After
Mean	0.0295	0.0348	0.0350
Min value	0.0191	0.0274	0.0261
Max value	0.0428	0.0408	0.0465

	Before – During	During - After
Mean difference (%)	+18	+1



(a)
The Average of Carbon Monoxide Before MCO (Jan - Mar 2020)
MALAYSIA
SINGAPORE
Latitude degree
Longitude degree
Total column (mol/m²)
(b)
The Average of Carbon Monoxide During MCO (Mar - Dec 2020)
MALAYSIA
SINGAPORE
Latitude degree
Longitude degree
Total column (mol/m²)

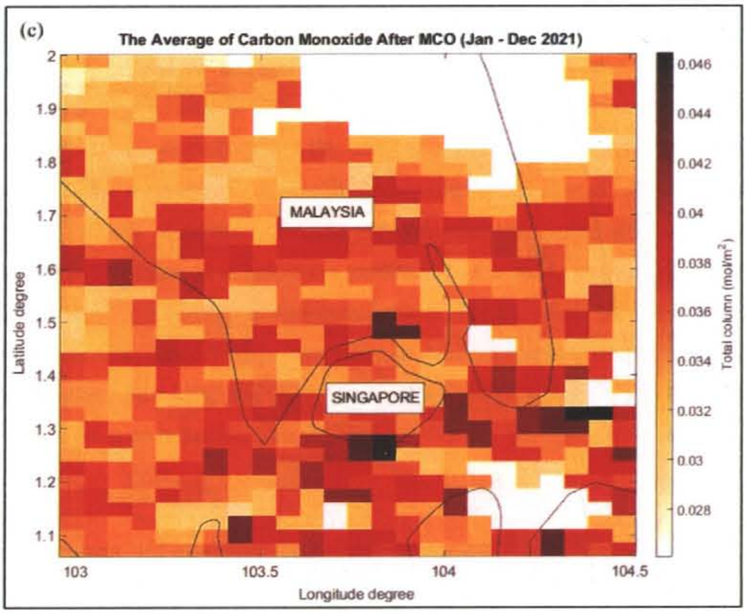


Figure 6 The average carbon monoxide concentration map around Iskandar Malaysia, where: (a) Before MCO; (b) During MCO; and (c) After MCO.

4.3 Flagship Zone Analysis

After analysing the average concentration of nitrogen dioxide and carbon monoxide. We extracted the data from the five (5) flagship zones location that were established by Iskandar Regional Development Agency as shown in Figure 1.

4.3.1 Nitrogen Dioxide (NO_2)

The variation of nitrogen dioxide concentration before and during MCO, and during and after MCO were shown in Table 7. Referring to before and during MCO, the only reduction was occurred at zone E (Senai – Skudai) with -1%, while others showing the increment where at zone D (Pasir Gudang) were the highest (+160%) followed at zone C (Tanjung Pelepas), zone B (Nusajaya), and zone A (Johor Bahru city) with, +115%, +74%, and +40%, respectively. Besides, for period during and after MCO, the variation shows at zone B is the highest (+174%) and at zone E (+30%), different with zone A, zone D, and zone C, where the location had a reduction after the MCO, with -40%, -25%, and -22%, respectively.

Table 7
Variation of NO_2 concentration changes in before, during, and after MCO.

Zones	Before (a)	During (b)	After (c)	Variation			
				a - b	b – c	a – b%	b – c%
A	3.521	4.918	2.957	1.397	1.961	+40	-40
B	0.860	1.501	4.122	0.641	2.621	+74	**+174**
C	2.600	5.585	4.342	2.989	1.242	+115	-22
D	2.090	5.424	4.042	3.334	1.381	**+160**	-25
E	2.326	2.307	3.016	0.019	0.709	-1	+30

* Bold indicate the highest changes, + = increase, - = decrease. All values in are $\mu mol/m^2$.

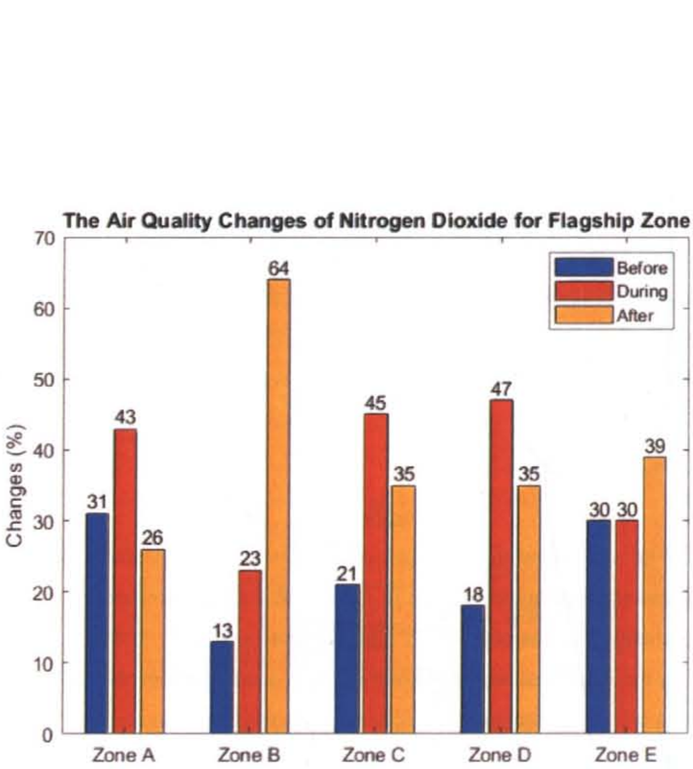


Figure 7 The overall changes of nitrogen dioxide based on different zones.

The bar graph in Figure 7 showed the percentage calculated based on every zone, where the value before, during, and after were total up. From the visual interpretation, all flagship zones had an increment of air pollution during the COVID-19 pandemic lockdown. Zone D were the highest increment with 47%, followed by zone C, zone A, and zone B, with 45%, 43%, and 23%, respectively. After the MCO, when all citizens of Iskandar Malaysia can do outside activities, the air pollution become increase in certain places such as at zone B with 64% and zone E 39%. While other zones have shown a good reduction.

4.3.2 Carbon Monoxide (**CO**)

Table 8 shows the variation of CO concentration, the highest increment was at zone C (+38%), followed by zone D (+35%), zone E (+24%), zone B (+20%), and zone A (+7%). As we observed during and after MCO, the highest increment was at zone E with +10% and the highest reduction was at zone C with -16% where it was the highest in before and during MCO. At zone A and zone B also showed a reduction with -3% and -9%, respectively.

Table 8
Variation of **CO** concentration changes in before, during, and after MCO.

Zones	Before (a)	During (b)	After (c)	Variation			
				a - b	b – c	a – b%	b – c%
A	0.033	0.036	0.035	0.003	0.001	+7	-3
B	0.031	0.037	0.033	0.006	0.004	+20	-9
C	0.028	0.039	0.032	0.011	0.007	**+38**	-16
D	0.027	0.036	0.039	0.009	0.003	+35	+7
E	0.028	0.035	0.038	0.007	0.003	+24	**+10**

* Bold indicate the highest changes, + = increase, - = decrease. All values in are $\mu mol/m^2$.

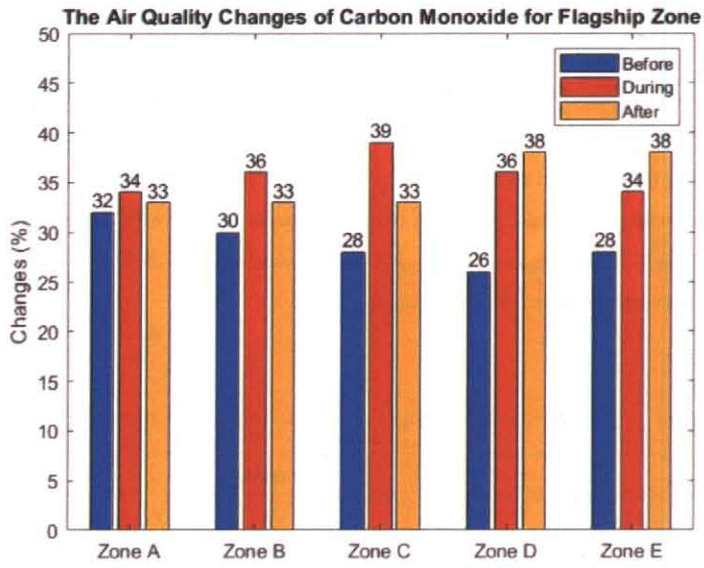


Figure 8 The overall changes of carbon monoxide based on different zones.

Figure 8 showed the changes percentage calculated based on every zone, where the value before, during, and after were total up. For carbon monoxide concentration showing that all zones were slightly increase in during MCO compared to before MCO. With zone C get the highest increment with 39%, and from the bar graph, all zones were in range 20% to 40%. The increment and reduction were not very exaggerated. Showing that, the production of carbon monoxide during and after MCO for five zone were very minimal and controlled.

4.4 Accuracy Assessment

In studies on air quality and climate, the root mean square error (RMSE) has been employed as a standard statistical indicator to assess model performance of satellite data and ground station. By normalising the nitrogen dioxide and carbon monoxide, Table 9 shows the value of RMSE at Pasir Gudang was the lowest (0.067) compared to Larkin (0.175), which tells us RMSE at Pasir Gudang was able to fit the dataset the best from Larkin. Lastly, for different statistical analyses, the correlation coefficient shows for both sites Larkin and Pasir Gudang a positive correlation (strong) which higher than 0.7 where Pasir Gudang was the highest (0.998) and Larkin (0.844).

Table 9
The value of Root Mean Square Error (RMSE), and correlation coefficient (r^2) for Larkin and Pasir Gudang, Johor.

	Larkin	**Pasir Gudang**
RMSE	0.175	0.067
r^2	0.844	0.998

* All values represent in unitless.

4.5 Discussion

In this study, we investigated NO_2 and CO changes in the period before, during, and post COVID-19 lockdown in Iskandar Malaysia, Johor. In addition, to deeply understand each air pollution change, we include the five flagship zones categorised by Iskandar Regional Development Authority (IRDA), as shown in Figure 1. This study aims to understand the air quality of the Iskandar Malaysia region by isolating three phases pre, during, and post. In addition, Iskandar Malaysia had an economic expansion and urbanisation (Nordin et al., 2016), which can be the primary source of air pollution. Referring a previous study shows that there is an increment of $PM_{2.5}$ for before and during MCO at Larkin with +2% and Pasir Gudang with +17.1%, while for MCO and MCO I, Larkin shows increment of +5.8% and Pasir Gudang +16.3%, lastly for MCO I and MCO II, Larkin indicate a reduction -7.2% and Pasir Gudang shows an increment +1.5% (Abdullah et al., 2020). The cause for $PM_{2.5}$ rose because of the forming particle from burning fuel and the chemical reaction that occur in the atmosphere from other air pollutants such as nitrogen dioxide (Seinfeld & Pandis, 2008).

As a result, for the NO_2 concentration in this study, showing a rising during MCO as shown in Table 5. From the result for the whole data NO_2 and CO explained that during a movement control order where the government has ordered a movement restriction, approximately for 10 months, there is an activity that can cause an increase in air pollution such as, service provider (delivery, shipping, heavy-industrial, and important government sector). According to Sharma (2020), higher SO_2 contributions from coal-fired power plants may have caused concentrations during the shutdown in 2020, whereas (Tobías et al., 2020), shipping emissions may be to blame for the increased SO_2 concentrations. From the statement designate the citizen have spent their time more on online shopping while they were having movement control order. Corresponding to (DHEC), sulphur dioxide and nitrogen dioxide are both parts of smog, and the primary source comes from the power plant, mobile vehicles, and burning coal and oil.

Referring to flagship zones bar graph over Iskandar Malaysia, Figure 7 shows that zone B (Nusajaya) get the highest increment for NO_2 before and after MCO, zone D (Eastern gate development) and zone E (Senai - Skudai) for CO concentration. The increasing air quality concentration in post MCO due to most of the sector during third and national recovery phase were open in helping the nation to generate the economic back after a few months of break. Referring to zone E (Senai – Skudai) is located at the international airport of Senai, a cyber city, manufacture of high technology and aerospace is the cause of increasing the air quality. Quotes from (Kanniah et al., 2021) state that, as one of the major economic sectors, the aviation industry is constantly growing, which has a significant impact on air pollution, climate change, and human health. As a result, the aviation industry globally emits 1.9% of greenhouse gases and is a 3.5% contributor to global warming.

Lastly, what authors can conclude from this study. Johor Bahru's city centre is unfriendly to pedestrians, with high traffic congestion and car accidents. Using public transportation to get around the city is time-consuming and unreliable is the causes of increasing in air pollution. When at the second phase and third phase of the MCO, there were several sectors can be open which mostly in services and some industrial sectors. Hence, there were some illegal factories run their business in order to generate their economy. Referring to these consequences, we can see the air pollution around Iskandar Malaysia were increase day by day. Relating this study with United Nations Sustainable Development Goals (SDGs) in achieving control air pollution, thus reducing the contamination. SDG 8, Decent work, and Economic Growth. Costs associated with air pollution are significant in high, low, and middle-income countries. These include consequences on the built environment, crop losses, productivity losses due to illness, and direst health care impacts. However, investing in new technologies that perform better in terms of emissions might open prospects for new employment and long-term growth. Opportunities are especially present in renewables, energy efficiency, and public transportation. Climate action, SDG 13. This objective is directly impacted by air pollution. The use of fossil fuel in industry, commerce, transportation, agriculture, and homes contributes significantly to climate change, which influences human health, food security, access to fresh water, and the marine environment.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the concentration of NO_2 and CO was observed by Sentinel-5P / TROPOMI satellite over Iskandar Malaysia, Johor. To support air quality monitoring at various scales of analysis, from the big cities to national, continental, or global coverages, the recently launched ESA Sentinel-5P satellite system produces free and open data products with a high spatial resolution available offline and in near-real-time. The result indicates that the MCO did not help much in reducing air pollution, especially for NO_2 and CO. Hench, the air pollution will gradually increase over the years due to social distancing, travelling and lack of public transport in Johor Bahru, where everyone will use their vehicle in their daily commute. Although air pollution does not affect people in the short term, accumulating air pollution in our surroundings can cause long term disease, greenhouse gases, climate change, an increase in land surface temperature, and result in an imbalance of nature. The objective of this study was achieved, as stated in 1.4, which is:

1. Accessing the nitrogen dioxide and carbon monoxide from the satellite Sentinel-5P/TROPOMI data product and ground station.
2. Gaining the best fit value for RMSE and strong correlation between the Sentinel-5P/TROPOMI data product and ground station data.
3. Generating map of concentration and analyse the air quality changes in pre, during, and post COVID-19 pandemic lockdown.

5.2 Limitations

All objectives have been achieved at the end of this study. However, there are obstructions and limitations have been identified. Firstly, the downloaded data were sorted by selecting one data in a week with same day for the whole period. Due to space limitation and time consuming. Secondly, the MCO phase (1, 2, and 3) in this study were average same goes to after MCO, the period is from January till December 2021. Hence, we cannot analyse the value of reduction during MCO for three phases. Apart from seeing the concentration reduction, we can analyse the increment of air pollution as of COVID-19 lockdown.

5.3 Recommendations

To increase the quality of the results, several recommendations are suggested. The recommendations presented are based on the difficulty and limitation addressed as follow:

1. Study on nitrogen dioxide concentration for the whole MCO period by downloading daily data from Copernicus.
2. Continue using the coding, in future the data can be process by days and generate the graphic interchange format (gif) for a good visualisation of air pollution changes.
3. Analyse with wind direction to gain more understanding from where the air pollution come from and where does its heading.

REFERENCES

Abdullah, S., Mansor, A. A., Napi, N. N. L. M., Mansor, W. N. W., Ahmed, A. N., Ismail, M., & Ramly, Z. T. A. (2020). Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic. *Science of the Total Environment*, *729*, 139022. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.139022

Aschi, M., & Largo, A. (2003). Reactivity of gaseous protonated ozone: A computational investigation on the carbon monoxide oxidation reaction. *International Journal of Mass Spectrometry*, *228*(2-3), 613-627.

Baharudin, S., Waked, H. N., & Paimen, M. S. (2021). MCO in Malaysia: Consumer confidence and households' responses. *Jurnal Ekonomi Malaysia*, *55*(1), 99-112.

BH Online. (2021, January 12). *Kronologi pelaksanaan fasa PKP*. https://www.bharian.com.my/berita/nasional/2021/01/775155/kronologi-pelaksanaan-fasa-pkp

Ciotti, M., Ciccozzi, M., Terrinoni, A., Jiang, W.-C., Wang, C.-B., & Bernardini, S. (2020). The COVID-19 pandemic. *Critical reviews in clinical laboratory sciences*, *57*(6), 365-388.

Control, S. C. D. o. H. a. E. *Nitrogen Dioxide & Sulfur Dioxide*. Retrieved August 22 from https://scdhec.gov/sites/default/files/Library/CR-008071.pdf

Department of Statistics Malaysia. (2021, July 15). *Current Population Estimates, Malaysia, 2021*. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=ZjJOSnpJR21sQWVUcUp6ODRudm5JZz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09

Dunlea, E., Herndon, S., Nelson, D., Volkamer, R., San Martini, F., Sheehy, P., . . . Lamb, B. (2007). Evaluation of nitrogen dioxide chemiluminescence monitors in a polluted urban environment. *Atmospheric Chemistry and Physics*, *7*(10), 2691-2704.

German Aerospace Center. (2018, July 11, 2018). *Ac-cu-rate air pol-lu-tion mea-sure-ments – the Sen-tinel-5P da-ta ser-vice com-mences op-er-a-tions*. Retrieved January 19, 2022 from https://www.dlr.de/content/en/articles/news/2018/3/20180711_accurate-air-pollution-measurements-the-sentinel-5p-data-service-commences-operations_28852.html

Ghahremanloo, M., Lops, Y., Choi, Y., & Mousavinezhad, S. (2021). Impact of the COVID-19 outbreak on air pollution levels in East Asia. *Science of the Total Environment*, *754*, 142226. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.142226

Hashim, B. M., Al-Naseri, S. K., Al-Maliki, A., & Al-Ansari, N. (2021). Impact of COVID-19 lockdown on NO2, O3, PM2.5 and PM10 concentrations and assessing air quality changes in Baghdad, Iraq. *Science of the Total Environment*, *754*, 141978. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.141978

Ho, C. S., Matsuoka, Y., Simson, J., & Gomi, K. (2013). Low carbon urban development strategy in Malaysia–The case of Iskandar Malaysia development corridor. *Habitat International*, *37*, 43-51.

Iskandar Regional Development Authority. (2013). *Merintis Peluang Ke Arah Kemampanan*. https://iskandarmalaysia.com.my/wp-content/uploads/2021/07/IRDA13-ARBM-FA-CD.pdf

Kanniah, K. D., Zaman, N., Kaskaoutis, D. G., & Latif, M. T. (2020). COVID-19's impact on the atmospheric environment in the Southeast Asia region. *Science of the Total Environment*, *736*, Article 139658. https://doi.org/10.1016/j.scitotenv.2020.139658

Kanniah, K. D., Zaman, N. K., & Perumal, K. (2021). Analysis of NO 2 Tropospheric Column amount at Airports in Malaysia Before and during COVID-19 Pandemic Using SENTINEL-5P Tropomi Data. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *43*, 399-403.

Kaplan, G., Avdan, Z. Y., & Avdan, U. (2019). Spaceborne Nitrogen Dioxide Observations from the Sentinel-5P TROPOMI over Turkey. *Proceedings*, *18*(1), 4. https://www.mdpi.com/2504-3900/18/1/4

Kleipool, Q., Ludewig, A., Babić, L., Bartstra, R., Braak, R., Dierssen, W., . . . Leloux, J. (2018). Pre-launch calibration results of the TROPOMI payload on-board the Sentinel-5 Precursor satellite. *Atmospheric Measurement Techniques*, *11*(12), 6439-6479.

Levelt, P. F., Stein Zweers, D. C., Aben, I., Bauwens, M., Borsdorff, T., De Smedt, I., . . . Romahn, F. (2021). Air quality impacts of COVID-19 lockdown measures detected from space using high spatial resolution observations of multiple trace gases from Sentinel-5P/TROPOMI. *Atmospheric Chemistry and Physics Discussions*, 1-53.

Liu, Y.-C., Kuo, R.-L., & Shih, S.-R. (2020). COVID-19: The first documented coronavirus pandemic in history. *Biomedical journal*, *43*(4), 328-333.

Majlis Keselamatan Negara. (2022). *SOP Pelan Pemulihan Negara (PPN)*. Retrieved January 19, 2022 from https://www.mkn.gov.my/web/ms/sop-perintah-kawalan-pergerakan/

Metya, A., Dagupta, P., Halder, S., Chakraborty, S., & Tiwari, Y. K. (2020). COVID-19 Lockdowns Improve Air Quality in the South-East Asian Regions, as Seen by the Remote Sensing Satellites. *Aerosol and Air Quality Research*, *20*(8), 1772-1782. https://doi.org/10.4209/aaqr.2020.05.0240

Minqiang, Z., Jingyi, J., Bavo, L., Bart, D., Mahesh, K. S., & Martine, D. M. (2021). Change of CO Concentration Due to the COVID-19 Lockdown in China Observed by Surface and Satellite Observations. *Remote Sensing*, *13*(6), 1129. https://doi.org/https://doi.org/10.3390/rs13061129

Mohd Nadzir, M. S., Ooi, M. C. G., Alhasa, K. M., Bakar, M. A. A., Mohtar, A. A. A., Nor, M. F. F. M., . . . Nor, M. Z. M. (2020). The Impact of Movement Control Order (MCO) during Pandemic COVID-19 on Local Air Quality in an Urban Area of Klang Valley, Malaysia. *Aerosol and Air Quality Research*, *20*(6), 1237-1248. https://doi.org/10.4209/aaqr.2020.04.0163

Nordin, N., Majid, M. R., Chin Siong, H., & Kurata, G. (2016). CO-BENEFIT MODELING AND OPTIMIZATION OF AIR POLLUTION CONTROL IN ISKANDAR MALAYSIA: A METHODOLOGY USING BenMAP. *PLANNING MALAYSIA*, *14*(4). https://doi.org/10.21837/pm.v14i4.165

Othman, M., & Latif, M. T. (2021). Air pollution impacts from COVID-19 pandemic control strategies in Malaysia. *Journal of cleaner production, 291*, 125992-125992. https://doi.org/10.1016/j.jclepro.2021.125992

Prunet, P., Lezeaux, O., Camy-Peyret, C., & Thevenon, H. (2020). Analysis of the NO2 tropospheric product from S5P TROPOMI for monitoring pollution at city scale. *City and Environment Interactions, 8*, 100051. https://doi.org/https://doi.org/10.1016/j.cacint.2020.100051

Rizzo, A., & Glasson, J. (2012). Iskandar Malaysia. *Cities, 29*(6), 417-427. https://doi.org/https://doi.org/10.1016/j.cities.2011.03.003

Săvulescu, I., Bogdan-Andrei, M., Nistor, C., & Dobre, R. (2020). Nitrogen Dioxide (NO₂) Pollution Monitoring with Sentinel-5P Satellite Imagery over Europe during the Coronavirus Pandemic Outbreak. *Remote Sensing, 12*(21), 3575. https://doi.org/https://doi.org/10.3390/rs12213575

Scotland, T. *Air Quality Monitoring, Verification, and Adjustment*. Retrieved August 21 from https://www.transport.gov.scot/

Seinfeld, J., & Pandis, S. (2008). Atmospheric chemistry and physics. 1997. *New York*.

Sentinelhub. (2022). *Sentinel-5P L2*. Retrieved January 15, 2022 from https://docs.sentinel-hub.com/api/latest/data/sentinel-5p-l2/

Sharma, S., Zhang, M., Gao, J., Zhang, H., & Kota, S. H. (2020). Effect of restricted emissions during COVID-19 on air quality in India. *Science of the Total Environment, 728*, 138878.

Tang, K. H. D. (2022). Movement control as an effective measure against Covid-19 spread in Malaysia: an overview. *Journal of Public Health, 30*(3), 583-586. https://doi.org/10.1007/s10389-020-01316-w

The European Space Agency. (2022). *Sentinel-5P*. Retrieved January 14, 2022 from https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p

Tobías, A., Carnerero, C., Reche, C., Massagué, J., Via, M., Minguillón, M. C., . . . Querol, X. (2020). Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic. *Science of the Total Environment, 726*, 138540.

TROPOMI. (2022). *Level 2 Products*. Retrieved January 15, 2022 from http://www.tropomi.eu/data-products/level-2-products

United States Environmental Protection Agency. (2021). *Air Data Basic Information*. Retrieved January 16, 2022 from https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information

Usmani, R. S. A., Saeed, A., Abdullahi, A. M., Pillai, T. R., Jhanjhi, N. Z., & Hashem, I. A. T. (2020). Air pollution and its health impacts in Malaysia: a review. *Air Quality, Atmosphere & Health, 13*(9), 1093-1118.

Wang, D., Hu, B., Hu, C., Zhu, F., Liu, X., Zhang, J., . . . Peng, Z. (2020). Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus–Infected Pneumonia in Wuhan, China. *JAMA, 323*(11), 1061-1069. https://doi.org/10.1001/jama.2020.1585

World Air Quality Index Project. (2021). *Real-time Air Quality Index*. Retrieved January 16, 2022 from https://waqi.info/

World Health Organization. (2021a, February 21). *Coronavirus (COVID-19) in Malaysia*. Retrieved December 09, 2021 from https://www.who.int/malaysia/emergencies/covid-19-in-malaysia

World Health Organization. (2021b). *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and* *carbon monoxide*. World Health Organization. https://apps.who.int/iris/handle/10665/345329

World Health Organization. (2022a). *Air pollution*. Retrieved January 15, 2022 from https://www.who.int/health-topics/air-pollution#tab=tab_1

World Health Organization. (2022b, January 18). *Coronavirus disease (COVID-19) Weekly Epidemiological Update and Weekly Operational Update*. Retrieved January 29, 2022 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports

Worrell, E., Price, L., Martin, N., Hendriks, C., & Meida, L. O. (2001). Carbon dioxide emissions from the global cement industry. *Annual review of energy and the environment*, *26*(1), 303-329.

Zahari, M. A. Z., Majid, M. R., Ho, C. S., Kurata, G., Nadhirah, N., & Irina, S. Z. (2016). Relationship between land use composition and PM10 concentrations in Iskandar Malaysia. *Clean Technologies and Environmental Policy*, *18*(8), 2429-2439. https://doi.org/10.1007/s10098-016-1263-3

ABSTRACT

The COVID-19 pandemic is sweeping the globe, claiming hundreds of thousands of lives in just a few months. Because of the necessity of lockdown measures, most countries, including Malaysia, have enacted Movement Control Order (MCO) was effectively enforced on March 18, 2020, as a preventative measure to stem the disease's lethal spread. The concentrations of two criterion pollutions, Nitrogen Dioxide (NO_2) and Carbon Monoxide (CO) were measured at Iskandar Malaysia, Johor, before the lockdown from January 1 to March 17, 2020, during the lockdown from March 18 to December 31, 2020, and post lockdown from January 1 to December 31, 2021. The results demonstrate that NO_2 and CO concentration from COVID-19 lockdown did not decrease, especially during the movement control order phase, with an increment of 112% for NO_2 and 18% for CO. The primary causes of the air quality increase were that several sectors were closed during the MCO. Iskandar Malaysia was the industrial and economic sector for the southernmost point of Peninsular Malaysia, causing fossil fuel combustion, power plant, local burning activities, and home appliances. The increment did not solely depend on MCO; maybe there is another reason for that increment. This study is to understand the COVID-19 lockdown affecting the urban air quality in Iskandar Malaysia before, during, and post-COVID-19 pandemic lockdown.

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

Copyright @ Sekolah Pengajian Siswazah