UNIVERSITI PUTRA MALAYSIA

ASSESSING THE IMPACT OF COVID-19 MCO ON THE MUNICIPAL SOLID WASTE (MSW) GENERATION IN MALAYSIA AND ITS RELATIONSHIP WITH ENVIRONMENTAL EFFECTS AND HEALTH RISK

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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

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ABSTRACT

ASSESSING THE IMPACT OF COVID-19 MCO ON THE MUNICIPAL SOLID WASTE (MSW) GENERATION IN MALAYSIA AND ITS RELATIONSHIP WITH ENVIRONMENTAL EFFECTS AND HEALTH RISK

NURUL AZWA BINTI MUHAMAD TAMRIN

Introduction: Solid waste volume is expected to increase with the implementation of the COVID-19 Movement Control Order (MCO). The Solid Waste Management and Public Cleansing Corporation (SWCorp) indicate, more than 200,000 tonnes of domestic waste are expected to be generated each month. The importance of this study is to provide an insight of solid waste generation issues in Malaysia amid of COVID-19 pandemic. This study quantifies the environmental impact and health risk from solid waste generation in landfill process. **Objective:** To assess the potential impact of COVID-19 Movement Control Order (MCO) towards the Municipal Solid Waste (MSW) generation in Malaysia and its relationship with the environmental effects and health risk. **Methodology:** The study areas were the states adopted Act 672 in Peninsular Malaysia. The datasets of total solid waste (tonnes) were obtained from the Solid Waste and Public Cleansing Corporation (SWCorp). The mathematical models and statistical analysis were performed to analyse the data. The mathematical models from the Ministry of Housing and Local Government (KPKT, 2015), the United States Environmental Protection Agency (U.S. EPA, 1998; U.S. EPA, 2011) and Intergovernmental Panel on Climate Change (IPCC, 2013) were used to measure the Greenhouse gas (GHG) emissions, leachate production and health risk. **Results and Discussion:** A decreased trend of solid waste generation was observed from 2014 to 2020. The volume of domestic waste was the highest in Johor. There was a significant difference in the volume of solid waste generated before and during MCO in Quarter 2 ($P < 0.05$). In average, the amount of solid waste during MCO was lower (254,265.48 ± 185,323.51 t/yr) than before MCO (388,342.72 ± 303,995.89 t/yr). There was a significant reduction ($p<0.05$) in GHG emission and leachate production during MCO. The estimated total methane (104,904.59 t/yr) and carbon dioxide equivalent (2,622,614.67 t/yr) emission has reduced significantly during MCO. The estimated leachate production has reduced from 536,571.87 m^3/yr before MCO to 507,996.13 m^3/yr during MCO. Meanwhile, xylenes contributed the highest NMVOC emission during MCO (9.70E-01 m^3/yr). The carcinogenic risk and non-carcinogenic risk towards inhalation exposure to the selected NMVOC compounds were in acceptable limit with Hazard Quotient (HQ<1) and Lifetime Cancer Risk (LCR<1.0E-04). **Conclusion:** The COVID-19 MCO has significantly reduced the municipal solid waste generation in the country. This has significantly reduced the impact to the environment in terms of greenhouse gases emission and leachate production as well as to the health risk.

Keywords: COVID-19, Movement Control Order (MCO), solid waste, health risk, environmental impact

ABSTRAK

PENILAIAN IMPAK PERINTAH KAWALAN PERGERAKAN (PKP) TERHADAP GENERASI SISA PEPEJAL DI MALAYSIA DAN HUBUNGANNYA TERHADAP KESAN PERSEKITARAN DAN RISIKO KESIHATAN

NURU.L AZWA BINTI MUHAMAD TAMRIN

Pengenalan: Sejak permulaan Perintah Kawalan Gerakan (PKP) yang pertama di negeri-negeri yang menguatkuasakan Akta Pengurusan Sisa Pepejal dan Pembersihan Awam 2007 (Akta 672) telah menghasilkan lebih daripada 200,000 tan sampah domestik setiap bulan dari data yang disediakan oleh Sisa Pepejal Perbadanan Pengurusan dan Pembersihan Awam (SWCorp). Kepentingan kajian ini adalah untuk memberi gambaran mengenai isu penjanaan sisa pepejal di Malaysia di semasa wabak COVID-19. Hasil daripada kajian ini, akan memberikan perbandingan perbandingan terhadap penghasilan sisa pepejal di lapan negeri di Malaysia sebelum dan semasa perlaksanaan PKP untuk mengukur kesan persekitaran dan risiko kesihatan dari penjanaan sisa **Objective:** Untuk menilai kesan pelaksanaan Perintah Kawalan Pergerakan (PKP) terhadap generasi sisa pepejal dan hubungannya terhadap kesan alam sekitar dan risiko kesihatan. **Metodologi:** Kawasan kajian melibatkan negeri yang menggunakan Akta 672 seperti Kuala Lumpur, Putrajaya, Pahang, Perlis, Kedah, Negeri Sembilan, Melaka, dan Johor. Kumpulan data jumlah sisa pepejal (tan) diperoleh daripada Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam (PSPPA). Model matematik dan analisis statistik seperti Paired Sample T-test dan One-way ANOVA test dilakukan untuk menganalisis data Pelepasan gas rumah hijau (GRH), pengeluaran larut lesap dan risiko kesihatan. Model matematik digunakan daripada Kementerian Perumahan dan Kerajaan Tempatan (KPKT, 2015), Manual Anggaran Teknik Pelepasan dari Agensi Pelindungan Alam Sekitar Amerika Syarikat (U.S. EPA, 1998; U.S. EPA, 2011) dan Panel Antara Kerajaan mengenai Perubahan Iklim (IPCC, 2013). **Hasil Kajian**: Trend penurunan sisa pepejal yang menurun dari tahun 2014 hingga 2020 disebabkan oleh aktiviti pengasingan sampah. Komposisi sisa domestik yang dihasilkan adalah yang tertinggi dengan Johor menyumbang negeri yang menghasilkan sisa pepejal tertinggi. Terdapat perbezaan yang signifikan bagi jumlah penghasilan sisa pepejal bagi sebelum dan semasa PKP dan pada Suku Kedua (Q2) ($P<0,05$). Jumlah sisa pepejal semasa PKP lebih rendah (254,265,48 ± 185,323,51 t/thn) daripada sebelum PKP (388,342,72 ± 303,995,89 t/thn). Terdapat perbezaan yang signifikan ($p<0,05$) dalam pengeluaran pelepasan GRK dan larut lesap sebelum dan semasa PKP. Dianggarkan jumlah pelepasan metana dan karbon dioksida telah menurun kepada 104,904,59 t/thn dan 2,622,614,67 t/thn semasa PKP. Anggaran pengeluaran larut lesap semasa PKP adalah 507,996,13 m3/thn berbanding 536,571,87 m3/thn sebelum PKP. Sementara itu, xylenes menyumbang pelepasan NMVOC tertinggi semasa PKP (9.70E-01 m3/thn). Oleh itu, risiko karsinogenik dan risiko bukan karsinogenik terhadap pendedahan penyedutan kepada sebatian NMVOC berada dalam had yang dibenarkan dengan nilai darjah bahaya (HQ <1). dan Risiko Kanser Sepanjang Hayat (LCR<1.0E-04). **Kesimpulan:** COVID-19 PKP memberikan perbezaan yang signifikan dalam jumlah penjanaan sisa pepejal sebelum dan semasa PKP, kesan persekitaran dan risiko kesihatan. Oleh itu, dapatan kajian ini mencadangkan untuk pelan jangka panjang pengurusan sisa pepejal yang mapan dan untuk meningkatkan tahap kesedaran di kalangan masyarakat untuk mengawal dan mengurangkan penjanaan sisa pepejal secara berkesan dan cekap di Malaysia.

Kata kunci: COVID-19, Perintah Kawalan Pergerakan (PKP), sisa pepejal, risiko kesihatan, kesan alam sekitar

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LIST OF ABBREVIATIONS

AT	Averaging Time
BW	Body Weight
CO2	Carbon Dioxide
CO2-Eq	Carbon Dioxide Equivalent
C*i*	Concentration Of NMVOC
COVID-19	Coronavirus Disease Of 2019.
DOC	Degradable Organic Carbon
DOCF	Degradable Organic Carbon Fraction
DOSM	Department Of Statistics Malaysia
EPA	Environmental Protection Authority
ED	Exposure Duration
EF	Exposure Frequency
FOD	First Order Decay Model
LFG	Landfill Gas
LCA	Life Cycle Assessment
LCR	Lifetime Cancer Risk
CH4	Methane
F	Methane Fraction
KPKT	Ministry Of Housing and Local Government
MCO	Movement Control Order
MSW	Municipal Solid Waste
MSWF	Municipal Solid Waste Fraction
JPSPN	National Solid Waste Management Department
NMVOC	Non-Methane Volatile Organic Compounds
SWCorp	Solid Waste and Public Cleansing Corporation
C*P*	The Default Concentration Of NMVOC
MSWT	Total Municipal Solid Waste
VL	Volume Of Leachate

CHAPTER 1

INTRODUCTION

1.1 Study Background

The COVID-19 pandemic has brought tremendous impacts towards human lives globally (Rume & Islam, 2020). COVID-19 disease has been classified as a pandemic by World Health Organization (WHO) which had caused chaos on communities as the disease had not only caused global health crisis but humanitarian, economic, and societal disaster (United Nations (n.d.). The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or coronavirus illness 2019 was the causes this devastating infectious disease. The World Health Organization (WHO) reported that the COVID-19 outbreak had impacted 213 nations as of April 10, 2020, with 1,524,162 confirmed positive cases and 92,941 COVID-19 deaths (WHO, 2020).

Malaysia is no exception as this country was considered one of the world ten countries with the highest number of COVID-19 cases and the highest number of cases confirmed in any country in Southeast Asia on April 11, 2020 (Shah et al. 2020; GardaWorld, 2020). Due to that, several countries had imposed several methods in social and travel restriction, lockdown, business closures and quarantines to curb the spreading of this disease among the community in the country. This is because the primary method of disease transmission is through exposure to the respiratory fluid that contained COVID-19 virus among man to man (Center of Disease Control and Prevention (CDC), 2021). The strategies to isolate the disease are include lockdowns, business closures, travel restrictions, quarantines and social distancing were opted in many countries (The New York Times, 2020).

On March 18, 2020, Malaysia's Movement Control Order (MC0) came into effect, forcing the shutdown of all businesses except those who offer essential services and products (Tang, 2020). This MCO was imposed as one of the strategies by the Malaysian government to curb the spread of COVID-19 among the community. According to Elengoe (2020), there are six restrictions that have been imposed through this MCO. The strategies are focusing on social and travel restriction, closure of non-essential services from commercial, industrial and institutional, border closures, massive COVID-19 or health screening and temporarily forbid worship activities.

However, major environmental issues have arisen as a result of the pandemic, including the Municipal Solid Waste (MSW) management and hazardous clinical waste. The Solid Waste Association of North America (SWANA) has highlighted the possible changes in the volume and source of solid waste created as a result of the authorities' implementation of a lockdown to contain the illness outbreak (SWANA, 2020; Kulkarni & Anantharama, 2020). Besides, according to Smart Waste Report European Union (2020), Municipal solid waste management systems are projected to become more of a challenge as time passes, among many other unprecedented effects of the current pandemic. This is because solid waste can cause significant impact on land, underground water or water sources and air. During the unprecedented pandemic, the amount of trash generated, particularly household waste, has increased including face masks, plastic packaging from Personal Protective Equipment (PPE), and hazardous items such as batteries and empty chlorine bottles are examples of additional waste generated during the pandemic (Das et al., 2021). This is because people are panicking and trying to protect themselves from the disease while using PPE and stocked up their food and daily needs before lockdown measures imposed by the government. Malaysia also has seen a larger generation of MSW as reported by Waste Management Association of Malaysia (WMAM). Since the implementation of MCO, waste generation in residential areas has increased by 20% to 30%, possibly due to all family members are stayed at home and do various kind of activities at home during lockdown (The Star, 2020).

There is limited study highlight the implication of movement restriction due to the pandemic to the solid waste generation, especially in the developing country like Malaysia. Therefore, this study was designed to study the implication of MCO implementation towards solid waste generation in Malaysia and the environmental impact as well as health risk due to the generation of solid waste during COVID-19 pandemic.

1.2 Problem Statement

According to Naughton (2020), COVID-19 that currently affected global health and environmental quality, had the possibility to change the waste generation, composition and waste distribution. This is due to the fact that it can vary in different locations. One of the factors could be due to the shutdown of certain places that produced high waste such as large business operations and schools during lockdown which had declined in total waste. Besides, COVID-19 social distancing measures resulted in the closure of business and lessening waste production but shifting some of the solid waste generation to the households' waste volume (Naughton, 2020). Movement Control Order (MCO) was enforced throughout the country in Malaysia during the first wave of COVID-19 cases. The authorities also had mandated the people to stay at home for months as a strategy to curb the spread of the disease within the community. This possibly have increased the production of domestic waste at home.

Domestic waste in states that enforce the Solid Waste and Public Cleansing Management Act 2007 (Act 672) in Peninsular Malaysia has increased to 200,000 tonnes for each month since the implementation of the first Movement Control Order (MCO) or MCO 1.0 in March 18 2020 (Rahim, 2020). This is due to Malaysian experienced panic buying prior to the announcement made by Prime Minister, Tan Sri Muhyidin Yasin. From social media, many pictures of people lining up in long queues and supermarket shelves nearly empty have gone viral over the internet. Other countries also experienced the same thing amid the first wave of COVID-19 outbreak. This can be supported by a study from Keane and Neal (2021) which reported that panic has affected almost every nation in the world, although at different times and to varying degrees. One of the reasons behind it is due to people being concerned about a shortage of supplies (Manning-Schaffel, 2020). Through lockdown or stay at home orders, the households started to purchase food and other daily needs online. The popular food delivery services in Malaysia such as Food Panda, Grab and Lalamove had become the favoured alternative by Malaysians with more than two million deliveries made between July and September 2020 according to Grab Malaysia (Rahim, 2020). Other countries such as the United States have increased buying items online and food delivery and hoarded food and items which may result in some waste from spoilage and also food packaging.

Increase of domestic waste and plastic waste from PPEs in many countries during pandemic, pose significant risk to human health as well as to the environment. The MCO also potential to change the waste composition generated by the households during the pandemic. For example, according to the survey, food waste was the major composition detected in Malaysia's landfills in 2019 at the greatest amount of 30% and plastic placed was the second with 24.8% (Rahim, 2020). Therefore, the authorities have to establish a sustainable solid waste management. According to the World Bank, the global annual garbage production is expected to rise from 2.01 billion tonnes in 2016 to 3.5 billion tonnes by 2050 and constitute 5% of total world emission from the treatment and disposal (SDG, 2018).

Other than that, solid waste has great impact to environment as well as human health. Deposited of solid waste in the landfill released landfill gas such as methane gas and carbon dioxide. According to Karim Ghani et al. (2013), methane gas will cause climate change, where it is 21 times more potent than carbon dioxide, making it exceedingly dangerous. According to Siti Wahidah (2017), if landfilling becomes the primary disposal option, an increase of 50% in greenhouse gas emissions will worsen environmental degradation. When the landfill reaches its maximum capacity, the reliance on it creates a space limitation (Ying & Latifah, 2014).

Moreover, leachate that produced from landfill activity has possible to contribute to human health risk as it contained organic matter, inorganic compound, heavy metals and organic xenobiotics (Christensen et al., 2001). This type of compounds could be toxic and carcinogenic to human (Kalcˇ´ıkova et al., 2011). According to Davoli et al. (2010), when leachate reaches the soil and water, it has the potential to harm not only the ecosystem but also human health. Moreover, other than chronic health effects, landfilling activity also can cause transmission of communicable disease such as cholera, dysentery, dengue, diarrhoea, and leptospirosis as solid waste in landfill was the suitable breeding ground for mosquito and food supplies for rodents, flies and insects (Pradyumna, 2013).

There are limited studies found on the impact of the COVID-19 restriction movement on waste management especially in the developing country like Malaysia. Therefore, this study was designed to analyse the waste generation data before and during the movement restriction to understand the impact of it. It analyses the potential environmental impact such as GHG emission and leachate as well as the health risk. This study provides an insight of solid waste generation issues in Malaysia amid of COVID-19 pandemic.

1.3 Study Justification

The importance of this study is to provide an insight of solid waste generation issues in Malaysia amid of COVID-19 pandemic. This is essential to reduce the waste generation as at source and disposal to the landfill. Besides, as the landfill is the primary method of disposal in Malaysia, generation of solid waste will cause an impact to the environment and posed health risk to the public that lived nearby the landfill from landfilling activities. Besides, this study wants to improve and promote a better solid waste management in Malaysia.

Furthermore, the result from this study, will provide the comparison a comparison on solid waste generation in every state in Malaysia before and during MCO to quantify the environmental impact from waste generation in landfill process. Regards to the changes in waste composition during pandemic, it will increase the environmental impacts through introduction of pollutant to the environment such air and water.

Lastly this study is important for government to review the current Municipal Solid Waste in Malaysia due to COVID-19 pandemic has imposed significant impact to global not only to health but also to environment and economy. The SWCorp and Malaysian government will need to implement additional measures to speed up the current waste segregation activity in the states that adopted Act 672. Besides this study will provide an overview of the efficiency of those programs through indication by waste separation activity made by the public during pandemic.

1.4 Conceptual Framework

Figure 1.1 shows the conceptual framework of this research. The conceptual framework below describes the concept in this study from the beginning, the collection data. The assessment will be analyzed by using mathematical modelling and descriptive analysis to identify the contribution of solid waste generated before and during pandemic to the environment and health of the populations. The independent variables of this study are the solid waste generated before and during MCO while the dependent variables of this study are the effects of solid waste generated to the environment and health of the population.

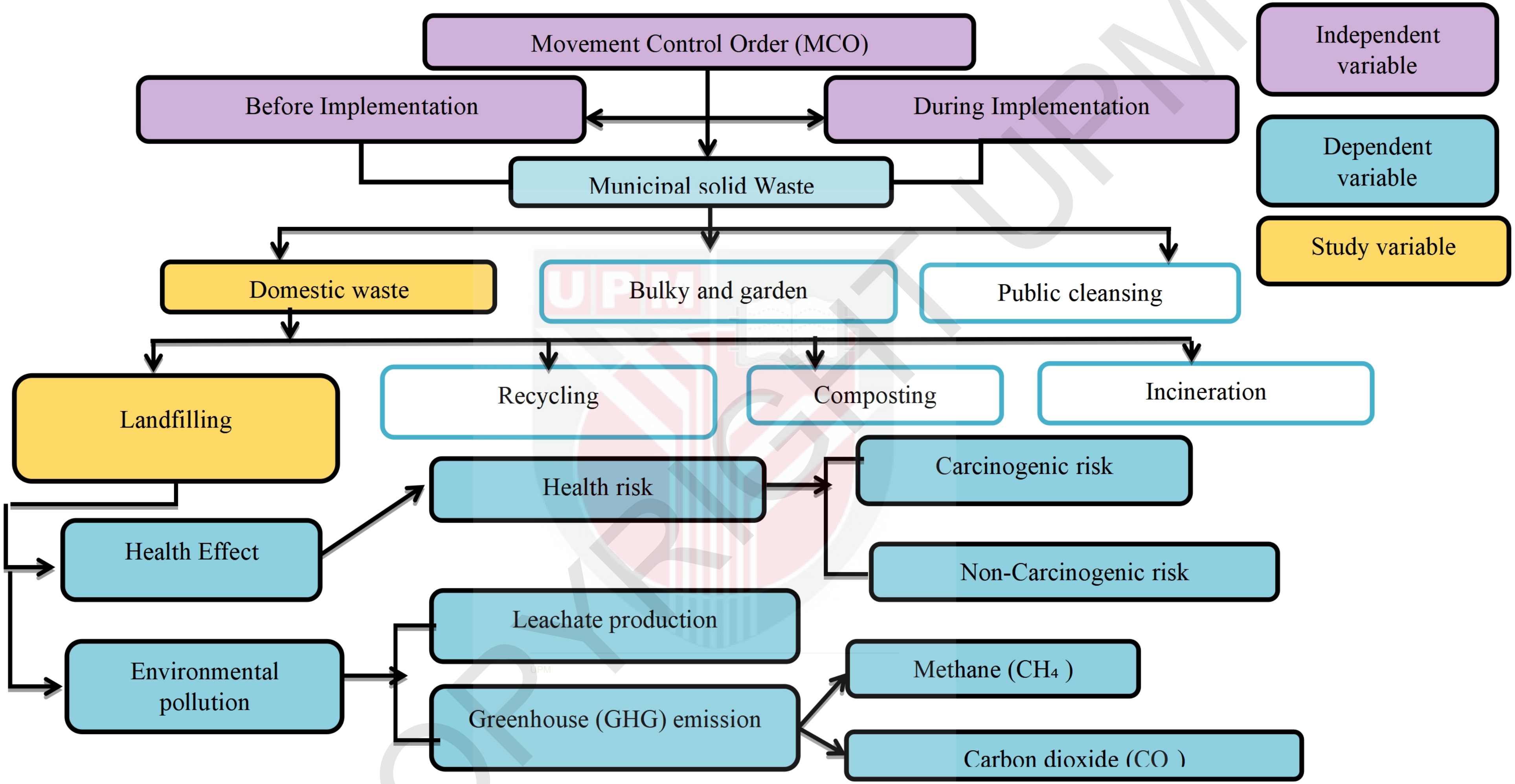


Figure 1.1: Conceptual framework

1.5 Definitions of Terms

1.5.1 Conceptual Definition

Municipal Solid Waste (MSW)

Municipal solid waste (MSW) is defined as waste collected by the municipality or disposed of at the municipal waste disposal site and includes residential, industrial, institutional, commercial, municipal, and construction and demolition waste (Hoornweg et al., 2015).

Before and during MCO

The Malaysian government implemented Movement Control (MCO) that was based on the Police Act 1967 and Prevention and Control of Infectious Disease Act (PCID Act 1988) in 4 phases. The 4 phases are Phase I (MCO I -from 18th to 31st March 2020); Phase II (MCO II - from 1st to 14th April 2020); Phase III (MCO III -from 15th to 28th April 2020) and the Phase IV (MCO IV from 29th April to 12th May 2020) (Rahim et al., 2021).

COVID-19 Pandemic

Coronavirus disease 2019 (COVID-19) is infectious disease that caused by a novel coronavirus which formerly called as 2019-nCoV and was first identified amid an outbreak of respiratory illness cases in Wuhan City, Hubei Province, China. COVID-19 has affects global health and environment as well (World Health Organization, 2019).

Health Risk

The likelihood that an individual's health has been damaged or will be damaged as a result of a specific exposure or set of exposure (United States Environmental Protection Agency, 2016)

Environmental impact

An environmental impact is defined as any change to the environment, whether adverse or beneficial, resulting from a facility's activities, products, or services.

1.5.2 Operational Definition

Municipal Solid Waste (MSW)

Municipal solid waste is a waste from commercial, institutional and household which comprises of three compositions such as domestic waste, bulky and garden waste and public cleansing waste. The weight of the total MSW by month and years from 2014 to 2020 that have been generated in Kuala Lumpur, Putrajaya, Johor, Negeri Sembilan, Perlis, Kedah, Malacca and Pahang were collected from Solid Waste Management and Public Cleansing Corporation (SWCorp).

Before and during MCO

In this study, during MCO period is referring to waste generated in year 2020 and before MCO period is referred to waste generated in year 2019. The comparison of waste generation before and during MCO will discussed further by quartile during MCO phases. Meanwhile for direct emission of greenhouse gases and leachate production before MCO were calculated using total volume of waste generated in year 2019 and total volume of waste generated in year 2020 for during MCO.

Health risk

The likelihood that an individual's health in the study areas has been damaged or will be damaged as a result of inhalation exposure towards Non-Methane Volatile Organic Compound (NMVOC) emission from landfilled domestic waste generation from study areas in landfill. The health risk estimated in this study was from the calculated inhalation exposure towards selected NMVOC compounds emission in the landfill before and during MCO. There are four types of compounds that were assessed include Halogenated compound, oxygenated, sulphur, aromatic and alkane compounds. In this study, the emission from all compounds. The health risk will be estimated in the form Non-carcinogenic and Carcinogenic risk where HQ<1 and LCR < 1.0E-4 is indicated as acceptable exposure limit.

Environmental impact

The measured difference of a predefined indicator (GHG emission and leachate production) with the intervention of (MCO) and without the intervention (MCO).

1.6 Research Questions

Questions that arise from this research were as follow:

1. What are the the impact of COVID-19 Movement Control Order (MCO) towards the Municipal Solid Waste (MSW) generation in Malaysia and its relationship with the GHG emission, leachate production and health risk?

1.7 Research Objectives

1.7.1 General Objective

To assess the impact of COVID-19 Movement Control Order (MCO) towards the Municipal Solid Waste (MSW) generation in Malaysia and its relationship with the environmental impact and health risk.

1.7.2 Specific Objectives

1. To determine the volume of Municipal Solid Waste (MSW) generation in Malaysia from year 2014 to 2020.
2. To compare the Municipal Solid Waste (MSW) generation in Malaysia by states before and during the MCO.
3. To compare the level of GHG emission (CO_2 , CH_4) by MSW generation before and during MCO in the study area
4. To compare the level of leachate production by MSW generation before and during MCO in the study area.
5. To assess the NMVOC emission level by MSW generation before and during MCO and health risk in the study area

1.8 Hypothesis

1. The volume of MSW generation in Malaysia by states was significantly higher during the MCO as compared to before MCO
2. The GHG emission (CO_2 CH_4) and leachate production, by MSW generation was significantly higher during the MCO as compared to before MCO in the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Movement Control Order (MCO) and COVID-19

2.1.1 COVID-19 disease

According to World Health Organization (WHO, n.d.), COVID-19 disease is a contagious disease that is caused by coronavirus. This disease started in Wuhan, China and has spread almost all over countries including Asia, Europe and North America (Ismail, 2020). This disease is said to be severe or acute compared to SARS-CoV. The mode of transmission of the disease is through airborne. Experts have different findings during the early of COVID-19 pandemic where COVID-19 is believed to be spread through touching contaminated surfaces with coronavirus such as pen, doorknobs, watertap, railways etc. However, until today there is on-going research about COVID-19. Based on the Centre of Disease Control and Prevention Center (CDC, 2021), primarily people get infected with COVID-19 through breathing of respiratory fluids infected with SARS-CoV-2 virus and three main methods of how people get infected which are, inhale of very small respiratory droplets or aerosol particles, direct splattering of those droplets or aerosol particles on mouth, nose, and eye and direct contact with surface contained the virus.

The COVID-19 disease is an acute disease as people who get infected with the virus shortly will develop the disease. The majority of patients infected with the COVID-19 virus will have mild to moderate respiratory symptoms and people over the age of 65, as well as those with underlying medical conditions such as cardiovascular disease, diabetes, chronic respiratory disease, and cancer, are at a higher risk of developing serious illness (WHO, n.d..)

In Malaysia, the first case reported was on 25 January 2020 with mostly imported cases and has urged Malaysian to take effective measures to contain the spreading of the disease within the community. One of them is through the establishment of the National Security Council (MKN) for COVID-19 management. The present situation of COVID-19 infection demands a faster and more efficient mitigation or intervention approach, according to Prime Minister Tan Sri Muhyiddin Yassin, who convened today's National Security Council (MKN) Special Meeting on COVID-19. This is to design a sound Standard Operating Procedure (SOP) that will be implemented as the inclined cases of COVID-19 in Malaysia. Despite that, Malaysia have onced to won over this disease during the first wave of COVID-19 outbreak in Malaysia. The Ministry of Health (MOH) had reported in July 2020, zero local Covid-19 transmissions for the second day in a row today, with six new instances of imported infections (CodeBlue, 2020). This is a triumph for Malaysia, particularly for the Malaysian frontliner.

Malaysian have developed different behaviors in response to COVID-19 outbreak in Malaysia. During the first wave of COVID-19, people started to stocked piles of face-mask, hand sanitizer, disinfectant and even hand gloves. These behaviors were because of fear that the COVID-19 disease might infect them and their families. Medical equipment industries that provided medical Personal Protective Equipment (PPE)s such as TopGlove had spiked on demand during this chaotic time. This can be supported by the articles of the increased share price among rubber glove makers in Malaysia reported by (Aziz, 2021), Besides, other than PPE, people also started going to hypermarkets in mass numbers to purchase in bulk essential needs such as food. According to retail surveys taken by the New Straits Times, rice, cooking oil, instant noodles, pasta, canned food and toilet paper were the hot items on the shelves at hypermarkets purchased by the shoppers (New Straits Times, 2020). The panic buying was seen not only in Malaysia but globally. There were significant increases in demand for storable products in the United States, which were mostly driven by frequently household purchased (O'Connell et al., 2020)

2.1.2 Movement Control Order (MCO)

On 18th March 2020, Malaysia was rocked by the announcement of a movement control order (PKP) by the Malaysian prime minister, Tan Sri Muhyidin Yasin. The Movement Control Order was based on the Prevention and Control of Infectious Diseases Act 1988 and the Police Act 1967. The MCO was to take effect for 14 days starting from 18th of March until 14th of April 2020. There are six measures under the MCO which are prohibition of large gatherings, restriction on travelling abroad, closure of country borders, closure of schools, closure of public and private higher institutions and lastly closure of all government and private office premises . Besides, the MCO is imposed based on the incubation period of COVID-19 disease which is 14 days. In conjunction with that, there are few phases of MCO that was implemented during first wave of COVID-19 in Malaysia.

Table 2.1 : Phases of MCO implementation during first wave of COVID-19 in Malaysia

MCO phases	Period
MCO phase 1	18 - 31 March

MCO phase 2	1 - 14 April
MCO phase 3	15 - 28 April
MCO phase 4	29 April - 3 May
Conditional Movement Control Order (CMCO)	4 May - 9 June
Recovery Movement Control Order (RMCO)	10 June - 31 December

2.1.3 Positive and Negative impact of pandemic

Since the occurrence of pandemic of COVID-19, there are positive and negative effects of COVID-19 pandemics. According to Rume and Islam (2020), the pandemic scenario improves air quality in different cities across the world, decreases GHG emissions, reduces water pollution and noise, and relieves pressure on tourist sites where it may help with the ecological system's repair. Meanwhile the negative impact of pandemic includes raised volume of medical waste, haphazard usage and disposal of disinfectants, masks, and gloves, as well as a continual weight of untreated wastes endangering the environment. Besides, as the economic activity appears to be returning shortly after the epidemic, these situations might change (Rume & Islam, 2020)

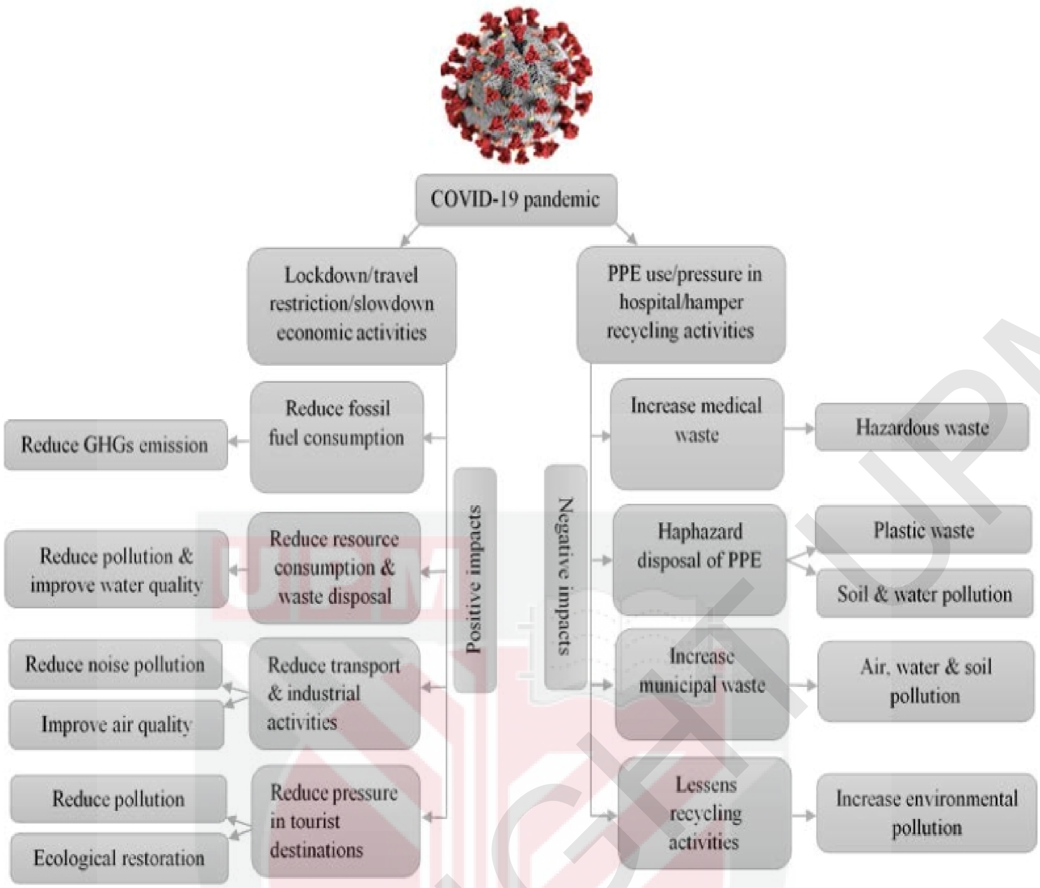


Figure 2.1: The positive and negative impacts of COVID-19 pandemic (Rume and Islam 2020)

2.2 Municipal Solid Waste (MSW)

2.2.1 Municipal solid waste

According to United States Protection Agency (USEPA, n.d.) Muncipal solid waste or (MSW), often known as trash or rubbish which is made up of daily objects such as product packaging, grass clippings, furniture, clothes, bottles, food scraps, newspapers, appliances, paint, and batteries that we use and then discard every day. Besides, they can be found in our homes, schools, hospitals, and workplaces. There are three practices that are commonly used to treat and manage MSW. The first method is source reduction. This is to prevent waste generation at the source. Source reduction function to reduce the quantity of waste that cannot be recycled while simultaneously making the waste less harmful. According to Skinner (2004), trash reduction measures are critical for halting or slowing the per-capita increase in waste creation. The second method is recycling. The recycling process is the process of recovering useful materials from waste, such as paper, glass, plastic, and metals, for reuse in new goods, hence lowering the amount of new raw materials required. There are many benefits of recycling for the environment which include protecting habitats and wildlife, conserving natural resources, decreased demand for raw materials, energy conservation, reducing potential climate change through reducing carbon dioxide emission, less expensive methods than waste collection and disposal methods and helps to combat youth unemployment (Friends of the earth, 2018). The last practice that is commonly used to treat MSW is composting. The process involves collecting organic waste, such as leftover food and yard scraps, and storing it in a way that allows it to naturally decompose. The compost that is created can subsequently be used as a natural fertilizer (USEPA, n.d.).

2.2.2 Solid waste generation

Solid waste generation is one of the huge problems that can have a significant impact on the environment. According to Latifah et al. (2018), the amount of solid trash generated each year is increasing as a result of global economic, evolving technologies that propel urbanization, and population growth. Besides, Hoornweg and Bhada-Tata (2012) reported in the study that every year, 1.3 billion tons of solid trash are collected around the world, with this figure anticipated to rise to 2.2 billion tonnes by 2025. Malaysia is also facing the same thing and solid waste and environmental pollution are never ending issues in this country until today.

Based on Iacovidou and Ng (2020), Malaysia has failed to achieve its 2020 goals of diverting 40% of waste from landfills and increasing recycling rates to 22%. Only 10.5% of waste was recycled, according to reports and nearly 90% of trash was reportedly disposed of in sanitary landfills. Furthermore, Malaysia is said to generate a massive amount of municipal solid garbage, estimated to be around 33,000 t/d, or 1.17 kilogram per person every day (Iacovidou & Ng, 2020).

According to the National Solid Waste Management Department (JPSPN), service providers hired by local governments to collect and dispose of municipal solid waste (MSW) frequently illegally collect and combine the MSW with commercial and industrial waste. This is because, these service providers wanted to claim more money from the authorities by increasing their load and trips to the landfill which resulting the government to considered raising landfill gate fees (Lacovidou & Ng, 2020).

However, these plans were cancelled as it can promote illegal dumping and fly-tipping.

The main Municipal solid waste composition in Malaysia is domestic waste, public cleansing waste and bulky and garden waste. Besides, Armi Abu Samah et al. (2013), reported that the commercial, institutional, industrial, and market activities all contribute to the waste composition in Malaysia. As shown in **Figure 2.1**, food waste make up the largest portion of the domestic waste produced by the households, accounting for around 44.5 % and the second placed is plastic waste with 13.2%.

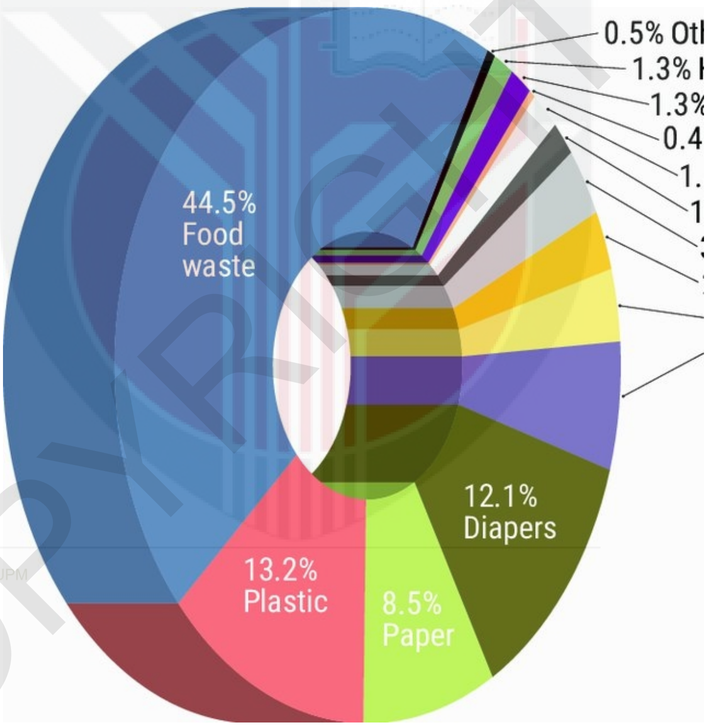


Figure 2.1: Malaysian Household Waste Composition (Seadon et al., 2017)

2.3 Environmental and health impact of landfill

2.3.1 Biogas emission from landfill

According to the Intergovernmental and Panel on Climate Change (IPCC, 2013), methane is 28 times larger than carbon dioxide for over the past 100 years that potentially contribute to global warming. Methane and carbon dioxide are the biogas that produced during landfilling activity. Besides, according to reports, landfills emit 50% methane, 45% carbon dioxide, and 5% other gases such as non-methane volatile organic compounds (NMVOC) (Yucekaya, 2014; Tomonori et al., 2011).

Landfill is one the disposal method to treat waste. Based on Environmental Protection Agency (EPA), landfills are well-designed and maintained sites for solid waste disposal. To ensure compliance with federal requirements, they are placed, designed, operated, and monitored. Besides, landfill also help to safeguard the environment from contaminants in the waste streams.

However, the landfill is regarded as the primary source of potential global warming (GWP). According to earlier studies in Thailand, a landfill emits 62% of greenhouse gases (GHG), or 3 million tonnes of CO2-eq, per year. (Liamsanguan & Gheewala, 2008; Inazumi, Ohtsu, Shiotani, & Katsumi, 2011; Menikpura, Gheewala, & Bonnet 2012). In Malaysia, 97 percent of waste disposal in open dumps provides 100% of GWP when compared to alternative methods. Another option is to use a 50% combination of open dump and sanitary landfill, which could also contribute to 50% of GWP (Saheri, Mir, Basri, Mahmood & Begum, 2012). As the amount of waste being disposed of increases, GHG emissions are expected to rise from 7.08 million tonnes in 2000 to 14.87 million tonnes in 2030 due to increasing waste dumped into landfill every year (Sie et al., 2014)

2.3.2 Leachate in landfill

Leachate is by definition the liquid that generated when rainwater filters through trash in a landfill. Whenever this liquid comes in interface with buried waste, the chemical or substance is leached out of the waste (USEPA, 2016). Waste composition that dumped in the landfill will affecting the leachate volume and its composition (Maiti et al., 2016). Besides, moisture content, age of landfill, rainfall intensity and land area also affecting the leachate product (Aziz et al., 2012; Adhikari et al., 2014; Ibrahim Mahmood & Othman, 2017).

Figure 2.2 shows a schematic design of landfill where a sanitary landfill is equipped with composite liner to prevent the leak of leachate and contaminate the groundwater which eventually pollute human drinking water sources.

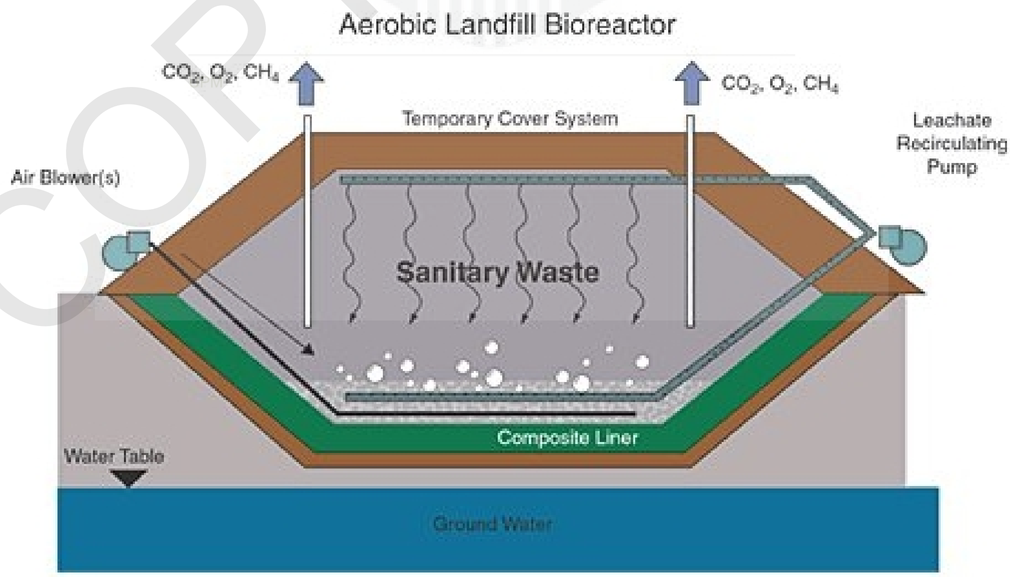


Figure 2.2 Schematic design of landfill (Aziz, 2013)

The problem involving leachate is that, it contains heavy metals that can contaminate the environment such as soil, water and land. For example, a study conducted by Sharifah et al. (2015), it found that the topsoil of non-sanitary landfill in Selangor contains high concentration of heavy metals. Not only it can endanger human lives but also to animals that eat contaminate crops from the polluted soil. Besides, another study by Mohd Raihan et al. (2011), found that the non-sanitary landfill in Ampar Tenang had damaged the groundwater and also surface water nearby. Other than that, landfill where it is an open dumping of solid waste can be the potential breeding sites of mosquito. This is because mosquito can breed in container that contained little amount of water which then will leads to dengue cases. Other study by Pradyumna (2013) has mentioned the same as solid waste disposal can pollute the soil, air, and water, providing a breeding ground for biological vectors that can spread diseases such diarrhoea, dysentery, food poisoning, leptospirosis, and bacterial infection.

Aside from communicable disease, non-communicable disease that can arises from leachate in landfill is cancer risk. This is due to heavy metal contains in the leachate. The heavy metal that can be found in landfill include cadmium where the International Agency for Research on Cancer (IARC) has classified cadmium under Group 1 carcinogenic. Previous study that can support this study is Carpenter et al., (2008) found that long-term contaminant exposure from landfill by products can cause cancer, chronic respiratory disease, cardiovascular disease, and nerve disorders in their study.

2.3.3 Exposure to NMVOC

According to European Environmental Agency (n.d.), NMVOCs (non-methane volatile organic compounds) are a group of organic chemicals that have a wide range of chemical compositions yet act identically in the atmosphere. NMVOCs are released into the atmosphere through a range of processes, including combustion, solvent use, and manufacturing. Ground-level (tropospheric) ozone is formed in part by NMVOCs. There are different type of categories of compound under NMVOC which include halogenated compound, oxygenated compound, sulphur compound, aromatic compound, alkenes compound, alkanes compound and nitrogenous compound (Wu et al., 2018; Yao et al., 2019). Furthermore, certain NMVOC species or groups, such as benzene and 1,3 butadiene, are toxic to humans. Thus, quantifying overall NMVOC emissions will gives an indicator of the most harmful NMVOCs' emission trends. This is because of its harmful effects on human health such as tropospheric ozone where it is a significant air contaminant. Other than that, landfill is one of the sources of NMVOC emission where a previous study found that, Hydrogen sulfide which emits high odour is high in the landfill due to organic waste degraded by the bacteria in the landfill (Wu et al., 2018). In terms of health risk, there is limited studies reported on health risk from emission of NMVOC from landfill. Besides, most of the findings found that the NMVOC exposure did not cause carcinogenic risk and carcinogenic risk. For example, a study by Davali et al. (2010), where the inhalation exposure to VOC for all groups were below acceptable limit.

CHAPTER 3

METHODOLOGY

3.1 Study Design

The is a cross-sectional study that aimed to assess the impacts of COVID-19 Movement Control Order (MCO) towards the Municipal Solid Waste (MSW) generation in Malaysia and its relationship with the environmental health effect. This study is useful in terms of estimating the emission of environmental pollutants such as GHG, leachate, non-methane volatile organic compounds (NMVOC) as well as health risks that are indirectly caused by increasing solid waste generation in our country.

There are three main impacts which are solid waste generation, environment and health. The environmental impact includes GHG emissions (methane and carbon dioxide) and leachate productions. Non-carcinogenic risk and carcinogenic risk were assessed by inhalation exposure to the estimated emission of NMVOC from landfill domestic waste among the three groups including men, women and children. The mathematical models were applied in the analysis of the impacts.

3.2 Study Location

This study took place in peninsular Malaysia where the states adopted a waste segregation scheme under the Solid Waste and Public Cleansing Management Act of 2007 (Act 672) were selected. The municipal solid waste in these areas is managed by the SWCorp. The study area includes federal territory of Kuala Lumpur and Putrajaya, and six states of Johor, Kedah, Pahang, Negeri Sembilan, Melaka and Perlis (Fig 3.1).

According to the Ministry of Housing and Local Government (n.d.), Malaysia government has mandated waste segregation at source beginning on 1st September 2015 which was enforced to the eight states that contributed the primary reason for selection of these study areas. The waste segregation scheme was under the Solid Waste and Public Cleansing Management Act of 2007 (Act 642) that intended to reduce waste at disposal sites and encourage recycling practice among householders in Malaysia. Besides, as stated in the Act 672, Part VIII of Section 74 (1) and (2), waste segregation at source is required, with families separating their garbage according to waste composition such as recyclable waste, residual waste and bulky or garden waste. Failure to comply with the rules will result in a RM1000 fine (Act 672, 2007). The Ministry of Housing and Local Government Malaysia (KPKT) is responsible for managing the solid waste through two main bodies which are the National Solid Waste Department (JPSPN) and Solid Waste Management and Public Cleansing Corporation (SWCorp) in the states that adopted Act 642 according to section (3) Part I, Act 642 from local authorities.

Meanwhile, for the collection and transportation services, private concessionaires were appointed that covered specific regions in Malaysia which include Alam Flora Sdn. Bhd for Central and East regions, Southern Waste Management Sdn. Bhd for Southern region and E-Idaman Sdn. Bhd for Northern region. The 2 + 1 system was introduced for the collection services in the states since 1st September 2015 where the non-recyclable materials will be collected twice a week while once a week for collection of recyclable materials and bulky waste

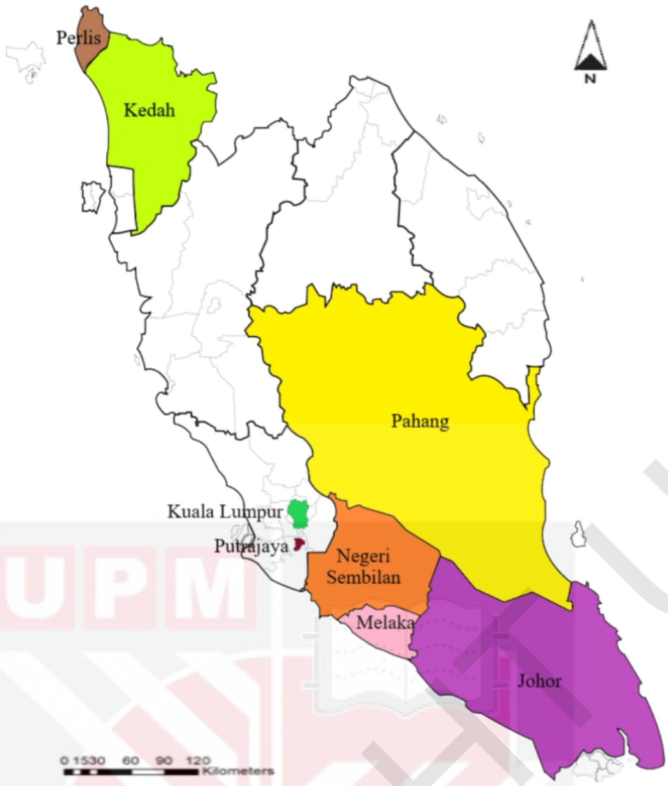


Figure 3.1: The location of the study areas (highlighted in the map)

Since municipal solid waste management is important as it is related to the economic status of a country and the lifestyle of its population (Sreenivasan et al., 2012), each state has different characteristics that contribute to the generation of solid waste in the country. Based on the size of the state from the Department of Statistics Malaysia (DOSM), (2019), data in 2017 reveals that the largest state in Peninsular Malaysia is Pahang with an area of 35,965 square kilometers (km2), followed by Johor (19,166 km2), Kedah (9,492 km2), Negeri Sembilan (6,656 km2), Malacca (1,720 km2), Perlis (816 km2), Kuala Lumpur (243 km2) and Putrajaya (49 km2) (DOSM, 2019). Meanwhile, based on population density, the most populous state after Selangor is Johor 3,742.20 million in 2018), followed by Kedah (2,163.70 million), Kuala Lumpur (1,795.20 million), Pahang (1,665.70 million), Negeri Sembilan (1,130.10 million), Perlis (253.80 million). Whereas, the least populated state is Wilayah

Persekutuan Putrajaya with 90.40 million population. However, in terms of population density, number of individuals per square kilometre, the most densely populated states in 2010 were W. P. Kuala Lumpur (6,891 persons) and W. P. Putrajaya (1,478 persons).

Meanwhile based on urbanisation factor, the highest was W. P. Kuala Lumpur and W. P. Putrajaya with 100 percent level of urbanisation. Other states followed by Melaka (86.5%), Johor (71.9%), Negeri Sembilan (66.5%) Kedah (64.6%). Perlis and Pahang had the lowest level of urbanisation in 2010 with 51.4% and 50.5%. Moreover, there have been reports of correlation between level of urbanization with per capita Gross Domestic Products (GDP) in many previous studies (Henderson, 2003). This is because urbanization will promote economic growth and increase urban population. Moreover, the state's economic performance determines the country's economic growth. Diversification of production concentration among states has had a diverse effect on overall GDP performance in Malaysia. In 2019, Kuala Lumpur and Johor was one of the 6 main states that had contributed to Malaysia's total GDP. In terms of GDP per capita, Kuala Lumpur and Melaka had recorded GDP per capita above national level with RM129,472 and RM49,172 (DOSM, 2020).

3.3 Scope of study

The scope of this study is the states that adopted Act 642 and excluded Selangor, Perak, Penang, Terengganu, Kelantan, Sarawak, and Sabah from the study.

Selection of secondary data only includes available data from SWCorp on collected municipal solid waste (domestic waste, bulky and garden waste, and public cleansing waste) in the 8 states from 2014 until 2020. For the environmental and health effect analysis only considered the volume of domestic waste (landfilled domestic waste) due to 80-90% of collected waste is domestic waste from the total volume of waste that will be sent to the landfills (JPSPN, 2013). Due to that, bulky and garden waste and public cleansing waste were excluded.

Besides, the NMVOC estimated direct emissions from landfilling activities and their health risk exposure were used for the health risk analysis. The greenhouse gases (GHG) and leachate were calculated using the amount of waste dumped in the landfill.

3.4. Data collection and management

Type of data collection used in this study was a secondary data collection method obtained from Solid Waste Management and Public Cleansing Corporation (SWCorp) through letter application. The data sets of municipal solid waste (MSW) for different compositions (ie: domestic waste, bulky and garden waste, and public cleansing waste) collected by year from 2014 to 2018 in Kuala Lumpur, Putrajaya, Johor,Negeri Sembilan, Melaka, Pahang, Perlis and Kedah were provided by SWCorp. However, for datasets in 2019 and 2020 were in the cumulative of three compositions provided by SWCorp where the fractions of each composition were estimated by percentage from the available data in 2014 to 2018.

The data was analysed and managed in Microsoft Excel by the states, years, and categories. For estimation of the environmental impact (GHG emissions and leachate production), health risk (Non-Methane Volatile Organic Compound (NMVOC) emission, carcinogenic and non-carcinogenic risk) were using mathematical equation and computed using mathematical formula in Excel. Only the data of landfilled domestic waste were used for the estimation

3.5 Study variables

The mathematical models that were used for analyzing the municipal solid waste (MSW) as followed: -

3.5.1 Environmental impact

As shown in **Table 3.1**, the summary of the mathematical model of environmental impact consists of the mathematical formula of Greenhouse gases emission (GHG) (CH4 and CO2-eq) and volume of leachate. The methodology was recommended by The Intergovernmental Panel on Climate Change (IPCC, 2006) for estimation of GHG and The Ministry of Housing and Local Government Malaysia (KPKT, 2015) mathematical model was used for estimation of leachate volume in landfill.

Table 3.1: Summary model of mathematical models of environmental impact (Uding et al., 2019)

Parameter	Mathematical models	Source
Methane emission **(CH_4)**	$$\mathbf{DOC = \sum[0.15F + 0.20G + 0.40P + 0.43W + 0.24T + 0.24D + 0.0O] - (1)}$$ **DOC** = Degradable organic carbon (DOC) F = fraction of food waste, G = fraction of garden waste, P = fraction of paper, W = fraction of wood, T = fraction of textile, D = fraction of diapers, O = fraction of other waste. $$\mathbf{TCH_4 = \sum[MSWT\ x\ MSWF\ x\ MCF\ x\ DOC\ x\ DOCF\ x\ F\ x\ \frac{16}{12}]}$$ **--- (2)** **CH4** = Methane (CH4) emission (tonne). **MSWT** = Volume of MSW (tonne). **MSWF** = Municipal solid waste fraction (MSWF) **MCF** = Methane correction factors (MCF) **DOC** = Degradable organic carbon (DOC) **DOCF** = degradable organic carbon fraction (DOCF)	(IPCC, 2006; 2019)

	F = Methane fraction (F) **16/12 =** The conversion of carbon (C) to CH4.	
Carbon dioxide equivalent **(CO_2-eq)**	$\mathbf{CO2 - eq = \sum[CH_4 \times 25]}$ **---(3)** **CO2-eq** = Carbon dioxide equivalent (tonne). $\mathbf{CH_4}$ = Estimated from equation **(2).** **25** = Global warming potential (GWP) factors.	(IPCC, 2006; 2019)
Leachate production	**VL =** $\sum[\mathbf{MSWT \times 0.21}]$ **---(4)** **VL** = volume of leachate (VL) discharge (**m^3**). **MSWT** = Volume of MSW (tonne). **0.21** = Volume of leachate per tonne of waste.	(KPKT, 2015)

a) GHG emissions (CH_4 and CO_2-eq)

The Intergovernmental Panel on Climate Change (IPCC) mathematical model in 2006 has described that, there are two main methods for estimation of methane in landfill which are the theoretical gas yield and the theoretical first-order kinetic methodologies or known as "First order decay model" (FOD). The first method was chosen in this study instead of FOD method because unavailability of good quality country-specific activity data on historical and current waste disposal such as dataset of waste disposal in landfills for more than ten years (Rangga et al., 2019). Besides, the first method was simpler as it was based on a mass balance equation and availability of landfilled domestic waste from the year 2019 to 2020 to compare potential estimation of direct emission of methane in landfill after the implementation of Movement Control Order (MCO). Furthermore, according to Rangga et al. (2019) this technique only offers an estimate of projected methane emissions in the year the waste is disposed of, rather than a realistic estimate and Jigar et al. (2014) does mentioned that the first method was recommended by the IPCC when specific data is not available as it will provide an acceptable annual estimation of CH_4 emissions.

As shown in Table 3.1, the methane gas estimation was calculated using equation (1) and (2) for domestic waste deposited in the landfill. According to IPCC (2006), the default carbon content value for food waste is 0.15, garden waste (0.20), paper and tetra pak (0.40), wood (0.43), textile (0.24), diapers (0.24) and other waste (0.0) (rubber, leather, plastics, metal (IPCC, 2006).

The range of degradable organic carbon (DOC) from 0.08 to 0.21 and IPCC recommended value 0.15. For this study DOC value is 0.16 as calculated using equation (1) below;

$$\mathbf{DOC=\sum[0.15F + 0.20G + 0.40P + 0.43W + 0.24T + 0.24D + 0.0O]---(1)}$$

F is the fraction of food waste, G is the fraction of garden waste, P is the fraction of paper, W is the fraction of wood, T is the fraction of textile, D is the fraction of diapers, and O is the fraction of other waste. Then, the methane gas emission will further be calculated using equation (2) as followed;

$$\mathbf{CH_4=\sum[MSWT\ x\ MSWF\ x\ MCF\ x\ DOC\ x\ DOCF\ x\ F\ x\ \ 16/12]---(2)}$$

MSWT is the total amount of municipal solid waste deposited in landfills (in tonnes) in a single year. Municipal solid waste fraction (MSWF) is 0.8 and was used according to Dong et al. (2010), who indicated in his study that Malaysia disposed of 80% of garbage in landfills. Meanwhile, methane correction factor (MCF) is ranging from 0.4 to 1.0, where value 0.6 is used for Malaysia landfill due to non-sanitary landfill still operating in Malaysia (IPCC, 2016; Anwar et al., 2012). The degradable organic carbon fraction (DOCF) is 0.77 (Anwar et al., 2012) and 0.55 value for methane fraction (F) was selected since the global estimate of CH_4 emissions from landfills is 5%. (Hoornweg & Perinaz, 2012). By multiplying the molecular weights of CH_4 (16 g/mol) and Carbon (C) (12 g/mol) with 16/12, carbon was converted to CH_4 (IPCC, 2006).

For carbon dioxide equivalent (CO2-eq) emission was estimated using equation (3) as below where CO2-eq is calculated by multiplying estimated CH_4 emissions by 25 to get 100-year global warming potential (GWP) values as CH_4 has 25 times the GWP of CO2 (IPCC, 2006)

$$\textbf{CO2-eq} = \sum[\mathbf{CH_4} \times \mathbf{25}] \quad \textbf{---(3)}$$

a) Leachate production

Leachate volume (VL) generated in the landfill was estimated using reported value by the KPKT. According to KPKT (2015), one tonne of waste generates 0.021 cubic meter (m3) of leachate as shown below;

$$\textbf{VL} = \sum[\textbf{MSWT} \times \textbf{0.21}] \quad \textbf{---(4)}$$

The leachate volume obtained by the total municipal solid waste (MSWT) deposited in the landfill multiplied with 0.21 values.

3.5.2 Health risk exposure

The summary of the mathematical model of health risk exposure consists of the mathematical formula of non-methane volatile organic compounds (NMVOC) emission using equation method of Air Pollutant Emission Factors (AP-42, Vol.1, 1998) recommended from the United States Environmental Protection Agency (U.S. EPA, 1998) and health risk exposure to the NMVOC such as non-carcinogenic and carcinogenic risk were using the equations in Exposure Factors Handbook, 2011 (U.S EPA, 2011) **(Table 3.2)**.

Table 3.2: Summary model of mathematical models of health risk (Uding et al., 2019)

Parameter	Mathematical models	Source
NMVOC emissions	$$\mathbf{NMVOC}\boldsymbol{i} = \sum \mathbf{i}\left[\mathbf{1.82\ x\ CH_4\ x}\ (\frac{\boldsymbol{CP}}{\mathbf{10^6}})\right] - (\mathbf{5})$$ **NMVOC*i*** = NMVOC emission (m3) **i** = the type of NMVOC (refer to **Table 3.3**). **1.82** = The multiplication factors. $\mathbf{CH_4}$= Estimated $\mathbf{CH_4}$ emission estimated using equation **(2).** $\boldsymbol{CP}$ = The default concentration of NMVOC **(Table 3.3)**	(U.S EPA, 1998)
Inhalation exposure	$$\mathbf{IE} = \sum \mathbf{i}[\boldsymbol{Ci\ x\ IR\ x\ EF\ x\ ED}])/(\boldsymbol{BW\ x\ AT})\text{---}(\mathbf{6})$$ **IE =** Inhalation exposure to NMVOC (m^3/kg/year). ***i* =** the type of NMVOC (refer to **Table 3.3**). **C*i*=** The estimated concentration of NMVOC emission using equation **(5)**. **IR** = inhalation rate (child, woman, and man). **EF** = The exposure frequency (one year). **ED** = The exposure duration (20 years). **BW** = The average body weight (child, woman, and man). **AT** = The averaging time	(U.S EPA, 2011)
Carcinogenic risk	**Lifetime cancer risk (LCR) = $\sum$i [IE × URF] ---(7)** **LCR =** Lifetime cancer risk (carcinogenic risk). **i =** the type of NMVOC (refer to **Table 3.3**). **IE =** Inhalation exposure to NMVOC (m3/kg/year). **URF =** unit risk factor **(Table 3.3)**.	(U.S EPA, 2011)
Non-carcinogenic risk	**Hazard Quotient (HQ) =$\sum$i (IE x) ---(8)** **HQ =** The hazard quotient (non-carcinogenic risk). ***i* =** the type of NMVOC (refer to **Table 3.3**). **IE =** Inhalation exposure to NMVOC (m^3/kg/year). **Rfc =** Reference concentrations (**Table 3.3**)	(U.S EPA, 2011)

a) NMVOC emission

A low quantity of NMVOC is typically present in landfill gas (LFG). Different organic hazardous air pollutants, greenhouse gases (GHG), and volatile organic compounds (VOC) are found in the NMVOC fractions. There were 40 compounds of NMVOC selected and the default concentration value provided by the U.S. EPA were used and analysed in this study as shown in **Table 3.3**.

$$.\mathbf{NMVOC}\boldsymbol{i} = \sum \boldsymbol{i}\left[\mathbf{1.82\ x\ CH_4\ x}\ (\frac{\boldsymbol{Ci}}{\mathbf{10^6}})\right] - (\mathbf{5})$$

The total volume of methane (TCH_4 in tonne) from equation (1) and (2) was used in the formula to estimate the emission of NMVOC in m^3 per year (m^3-year) unit. In this equation, the total volume of TCH_4 (tonne) was converted to m^3, which is 1 tonne equal to $0.42m^3$. The multiplication factors of 1.82 were used as 55% of CH4 and 45% of CO2 generated in the landfills.

The $\boldsymbol{i}$ refers to the type of NMVOC that was selected in this study and the default concentration of the compounds (C*i*) in part per million volumes (ppmv) were shown in Table 3.3. According to the U.S EPA (1998), when site-specific data is unavailable and air infiltration has been corrected, the default concentrations can be used to estimate emissions. The default concentrations (ppmv) were converted to m^3 by dividing them with 1×10^6.

b) Inhalation exposure to NMVOC compounds.

$$\mathbf{IE} = \sum \mathbf{i}[\boldsymbol{Ci\ x\ IR\ x\ EF\ x\ ED}])/(\boldsymbol{BW\ x\ AT})\text{---}\mathbf{(6)}$$

Inhalation exposure (IE) is the estimated exposure in m^3/kg/year to the selected compound of NMVOC as shown in **Table 3.3,** among children, woman and man from the concentration of NMVOC emission in the landfill. In this study, inhalation rates (IR) for the three groups varied, where 15 m^3/day for a child, 21 m^3/day for an adult woman, and 23 m^3/day for an adult man were used (US EPA, 2011; Nordic Council of Ministers, 2012). They were varied due to different sizes, physiology, behavior, and activity level. According to the U.S EPA (2011), children have large lung surface area per unit of body weight and rapid growth that contributes to the high resting metabolic rate and oxygen consumption rate per unit of body weight compared to adults. Besides, the average body weight (BW) for children, man, women that were used in this study also differs which include 31.80 kg (children), 66.56kg (adult man) and 58.44 kg (adult woman) (Azmi et al., 2009; US EPA, 2011). The exposure duration (ED) is based on the landfill lifespan, which is 20 years (KPKT, 2015) and the exposure frequency (EF) is one year (365 days). The averaging time (AT) for non-carcinogenic effect is equal to the exposure duration (ED) whereas carcinogenic effect, the averaging time for adult men is 72.7 years, while for adult women is 77.6 years (DOSM, 2019)

b) Carcinogenic risk.

$$\textbf{Lifetime cancer risk (LCR)} = \sum_i (\textbf{IE} \times \textbf{URF}) \text{ ---(7)}$$

The *i* refers to the selected NMVOC compound that were selected in this study and the inhalation unit risk factor (URF) was obtained from the Integrated Risk Information System (IRIS), US EPA as shown in **Table 3.3**

c) Non-carcinogenic risk.

$$\textbf{Hazard Quotient (HQ)} = \sum \mathbf{i}\ (\textbf{IE x } \boldsymbol{Rfc}) \text{ ---(8)}$$

The IE refers to reference concentrations (Rfc) for non-carcinogenic risk that was obtained from the Integrated Risk Information System (IRIS), US EPA.as shown in **Table 3.3.**

Table 3.3: The default concentrations, unit risk factors (URF), and reference concentration (Rfc) of NMVOC.

Category	NMVOC	Default concentration (ppmv)[a]	URF ($\mu g/m^3$)[b]	Rfc (mg/m^3)[c]
Halogenated compounds	1,1,2,2-Tetrachloroethane	1.11	NA	NA
	Methyl chloroform	0.48	NA	5
	Ethylidene dichloride	2.35	NA	NA
	Vinylidene chloride	0.2	NA	2×10^{-1}
	Ethylene dichloride	0.41	2.6×10^{-5}	NA
	Propylene dichloride	0.18	NA	4×10^{-3}
	Bromodichloromethane	3.13	NA	NA
	Carbon tetrachloride	0.004	6×10^{-6}	1×10^{-1}
	Chlorobenzene	0.25	NA	NA
	Chlorodifluoromethane	1.3	NA	5×10^{1}
	Chloroethane	1.25	NA	1×10^{1}
	Chloroform	0.03	2.3×10^{-5}	NA
	Chloromethane	1.21	NA	9×10^{-2}
	Dichlorobenzene	0.21	NA	8×10^{-1}
	Dichlorodifluoromethane	15.7	NA	NA
	Dichlorofluoromethane	2.62	NA	NA
	Dichloromethane	14.3	1×10^{-8}	6×10^{-1}
	Ethylene dibromide	0.001	6×10^{-4}	9×10^{-3}
	Trichloromethane	0.76	NA	NA
	Tetrachloroethylene	3.73	2.6×10^{-7}	4×10^{-2}
	t-1,2-dichloroethene	2.84	NA	NA
	Trichloroethene	2.82	4.1×10^{-6}	2×10^{-3}
	Vinyl chloride	7.34	8.8×10^{-6}	1×10^{-1}
Oxygenated compounds	2-Propanol	50.1	NA	NA
	Acetone	7.01	NA	NA
	Ethanol	27.2	NA	NA
	Methyl ethyl ketone	7.09	NA	5
	Methyl isobutyl ketone	1.87	NA	3
Sulphur compound	Carbon disulfide	0.58	NA	7×10^{-1}
	Carbonyl sulfide	0.49	NA	NA
	Dimethyl sulfide	7.82	NA	NA
	Ethyl mercaptan	2.28	NA	NA
	Hydrogen sulfide	35.5	NA	NA
	Methyl mercaptan	2.49	NA	NA
Aromatic compound	Ethylbenzene	4.61	NA	NA
	Xylenes	12.1	NA	1×10^{-1}
Alkanes	Butane	5.03	NA	NA
	Hexane	6.57	NA	7×10^{-1}
	Pentane	3.29	NA	1
	Propane	11.1	NA	NA

[a]Air Pollutant Emission Factors (AP-42, Vol.1, 1998) ([U.S. EPA], 1998).
[b]Unit risk factor (URF) for carcinogenic. (Integrated Risk Information System (IRIS), US EPA).
[c]Reference concentrations for non-carcinogenic (Rfc) (IRIS, US EPA).
[d]NA indicates that data are not available under the IRIS program.

3.6 Study Flowchart

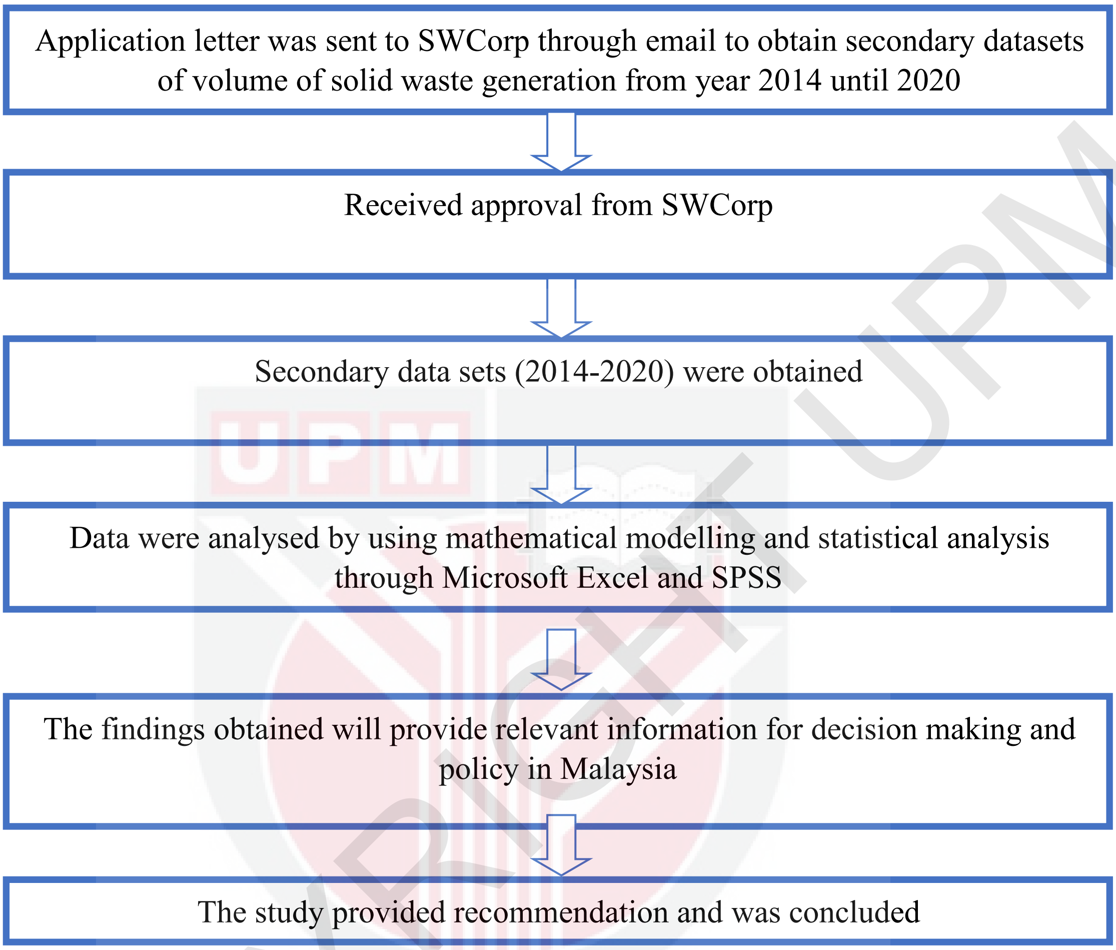


Figure 3.2: Research flowchart

3.7 Quality Assurance (QA) and Quality Control (QC)

In this study, Microsoft Excel 2016 was used to ensure quality assurance and quality control. To avoid any calculation errors, the mathematical models were inserted and programmed in the excel "function formula." The data was calculated automatically by Excel. Besides, all data obtained were tested for its normality before proceeding with statistical analysis., and data that are normally distributed were proceed with parametric statistical analysis. In addition, scatter plot diagram was used to remove outliers and detect typing errors

3.8 Data Analysis

The data obtained was analysed and managed by using Microsoft office excel and equation from Mathematical modelling. The type of analysis which was used for this study as shown in **Table 3.4,** based on the specific objectives in this study.

Table 3.4: Data Analysis outcomes

	Specific Objectives	Tests
1.	To determine the volume of Municipal Solid Waste (MSW) generation in Malaysia from year 2014 to 2020 by states.	Descriptive analysis
2.	To compare the Municipal Solid Waste (MSW) generation in Malaysia by states before and during MCO	Paired sample T-test
3.	To compare the level of GHG emission (CO2, CH4) by MSW generation before and during MCO in the study area	1-way Annova
4.	To compare the level of leachate production by MSW generation before and during MCO	1-way Annova
5.	To determine the level of NMVOC emission by MSW generation before and during MCO and health risk in the study area	1-way Annova

CHAPTER 4

RESULT

4.1 Solid waste generation and its composition in Malaysia

4.1.1 Solid waste generation in by year (2014-2020)

The volume of solid waste generation from year 2014 to 2020 in Malaysia is shown in **Figure 4.1**. The data contained total volume of collected waste includes domestic waste, bulky and garden waste and public cleansing waste in the states under Act 642 for 7 years that were obtained from SWCorp.

Based on the table, the total volume of solid waste for all composition produced in Malaysia has decreased from year 2014 to 2020. Year 2020 was recorded with the lowest waste generated (2,941,288.73 tonnes/year) with the mean ±SD of 367,661.09 ±293,046.94 t/yr). Whereas the highest volume of solid waste generated was in 2015 which is 3,495,085.25 with mean ±SD (436,885.66 ±351,542.54 t/yr).

4.1.2 Solid waste generation in Malaysia by states (2014-2020)

Figure 4.2, showed the volume of waste generated was significantly higher in Johor with the mean ±SD of 947,930.00 ±58,032.03 t/yr, followed by Kuala Lumpur (795,636.00 ±77,416.21 t/yr) and Kedah (490,118.64 ±62,018.12 t/yr). The lowest volume of waste generated was in Putrajaya (48,675.59 ±11,835.83 t/yr) and Perlis (52,588.07 ±13,877.91 t/yr).

4.1.3 Solid waste generation in Malaysia by regions (2014-2020)

Figure 4.3 showed the volume of waste generated was significantly higher in Southern region which consist of Johor and Malacca with the mean ±SD of 1,240,309.90 ±88,421.28 t/yr, followed by the Central region (Kuala Lumpur, Putrajaya, and Negeri Sembilan) with the mean ±SD of 1,107,072.00 ±83,504.97 t/yr. The lowest total of waste generated was in the East region with Pahang as the only state contribute to the total volume of waste at 2,215,020.34 t/yr with the mean ±SD of 316,431.48 ±41,907.55 t/yr.

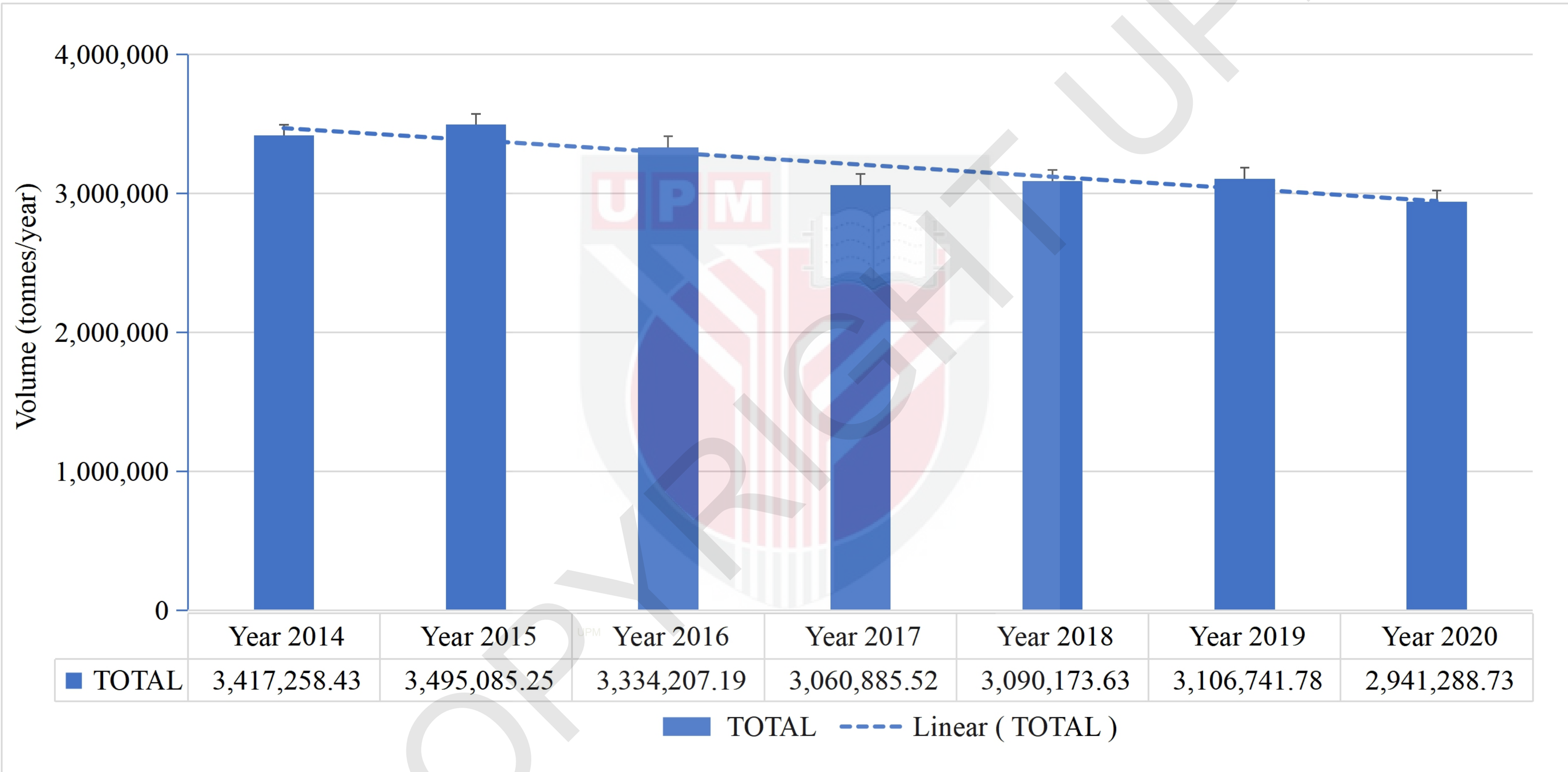
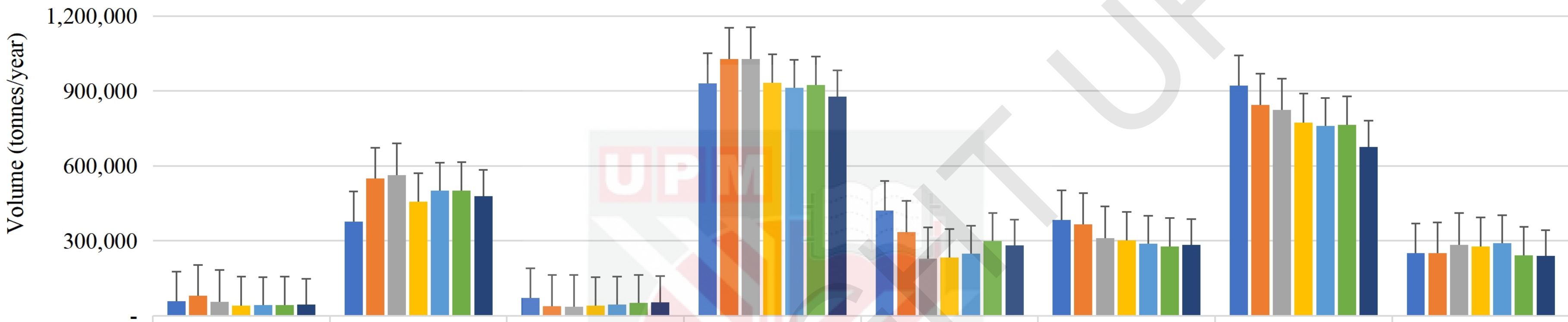
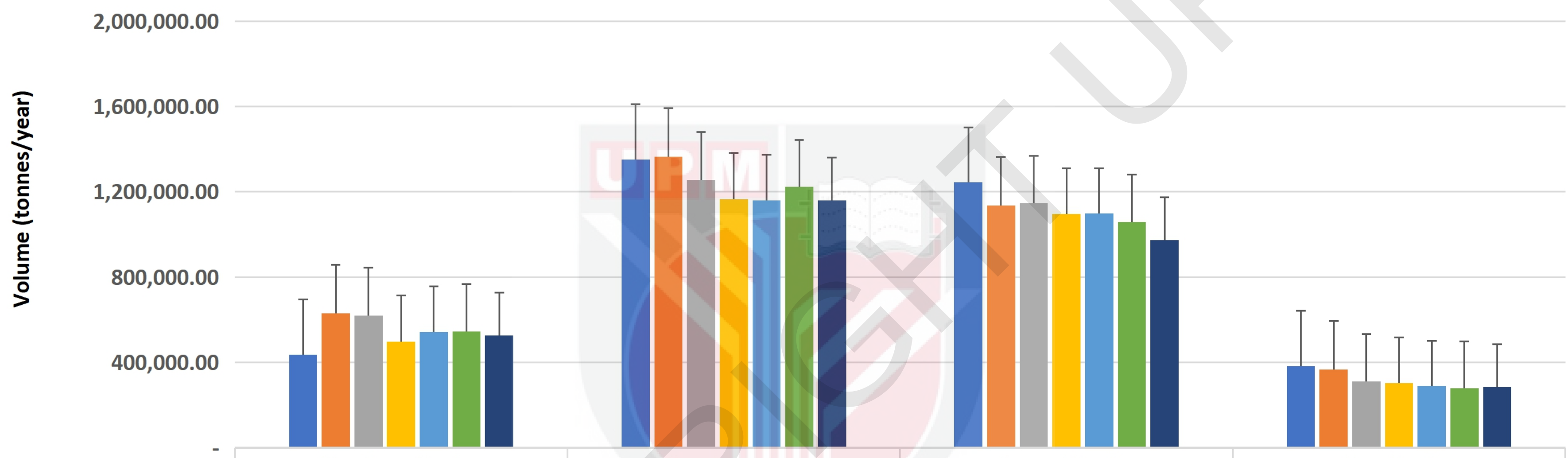


Figure 4.1: Total of solid waste generation (domestic waste, bulky and garden waste, public cleansing waste) (tonnes/year) in the states under Act 642 from year 2014-2020



	PERLIS	KEDAH	PUTRAJAYA	JOHOR	MALACCA	PAHANG	Kuala Lumpur	N. SEMBILAN
2014	58,614.33	378,086.39	71,432.73	931,436.32	420,719.20	384,074.79	922,667.03	250,227.64
2015	79,930.30	549,685.69	39,406.40	1,028,888.28	335,470.46	366,211.90	844,913.86	250,578.36
2016	56,494.00	563,945.90	37,531.67	1,028,157.26	228,390.64	310,977.97	823,710.90	284,998.85
2017	41,893.65	456,181.96	41,024.06	932,493.89	233,548.30	302,306.39	774,740.49	278,696.78
2018	42,179.55	500,843.36	45,429.35	912,112.00	247,948.84	289,311.85	761,182.38	291,166.30
2019	43,289.57	502,426.20	51,100.29	924,201.24	299,149.59	278,071.45	765,146.42	243,357.03
2020	45,715.06	479,660.95	54,804.64	878,221.00	281,432.29	284,065.99	677,090.92	240,297.88

Figure 4.2: Total volume of solid waste generation (tonnes/year) in Malaysia from 2014-2020 by states



	Northern Region	South Region	Central Region	East Region
2014	436,700.72	1,352,155.52	1,244,327.40	384,074.79
2014	629,615.99	1,364,358.74	1,134,898.62	366,211.90
2014	620,439.90	1,256,547.90	1,146,241.42	310,977.97
2014	498,075.61	1,166,042.19	1,094,461.33	302,306.39
2014	543,022.91	1,160,060.84	1,097,778.03	289,311.85
2014	545,715.77	1,223,350.83	1,059,603.74	278,071.45
2014	525,376.01	1,159,653.29	972,193.44	284,065.99

Figure 4.3: Total volume of solid waste generation (tonnes/year) in Malaysia from 2014-2020 by regions

4.1.3 Solid waste generation in Malaysia by its composition (2014-2020)

Solid waste generation in the states under Act 642 was classified into three types of composition namely (i) domestic waste, (ii) Bulky and garden waste, (iii) Public cleansing waste. **Figure 4.4** showed the domestic waste has the highest percentage (81%) with the mean ±SD of 2,635,256.80 ± 138,729.57 tonnes per year t/yr, followed by bulky and garden waste (13%) (416,092.87 ± 82,892.43 t/yr) and public cleansing waste (6%) (187,498.01± 87,508.85 t/yr). From 81% of generated domestic waste, the highest percentage was obtained from Johor which (31%) with the mean ±SD of 818,957.96 ±63,934.55 tonnes per year (t/yr), followed by Kuala Lumpur (23%) (616,542.32 ±36,381.25 t/yr), and Kedah (15%) (677,334.45 ±44,865.12 t/yr). The lowest volume of domestic waste was in Putrajaya (1%) (32,795.34 ±7,477.64 t/yr).

The volume of bulky and garden waste was high in Kuala Lumpur (35%) (146,381.82 ±47,976.55 t/yr), followed by Johor (26%) (110,499.91 ±49,627.85 t/yr), and Kedah (13%) (52,756.77 ±9,074.45 t/yr). Both Putrajaya and Perlis generated the lowest volume (2%), which was 8,549.19 ± 6,330.06 t/yr and 7,492.07 ± 2,816.99 t/yr respectively. For the public cleansing waste, it was highly generated in Kedah (27%) (50,186.59 ± 29,291.59 t/yr) and the lowest was in Perlis (2%) (3,914.94 ± 1,697.79 t/yr).

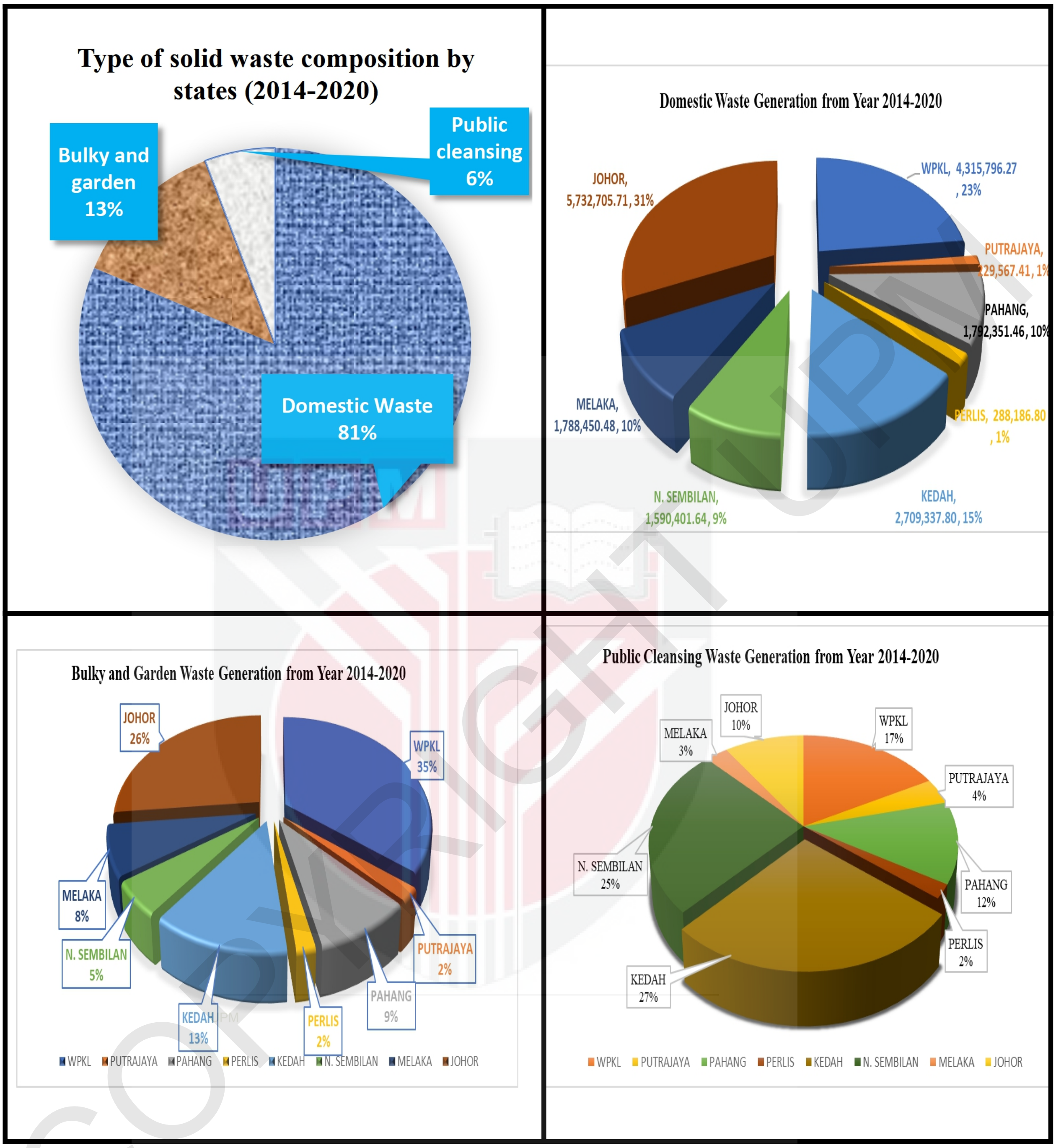


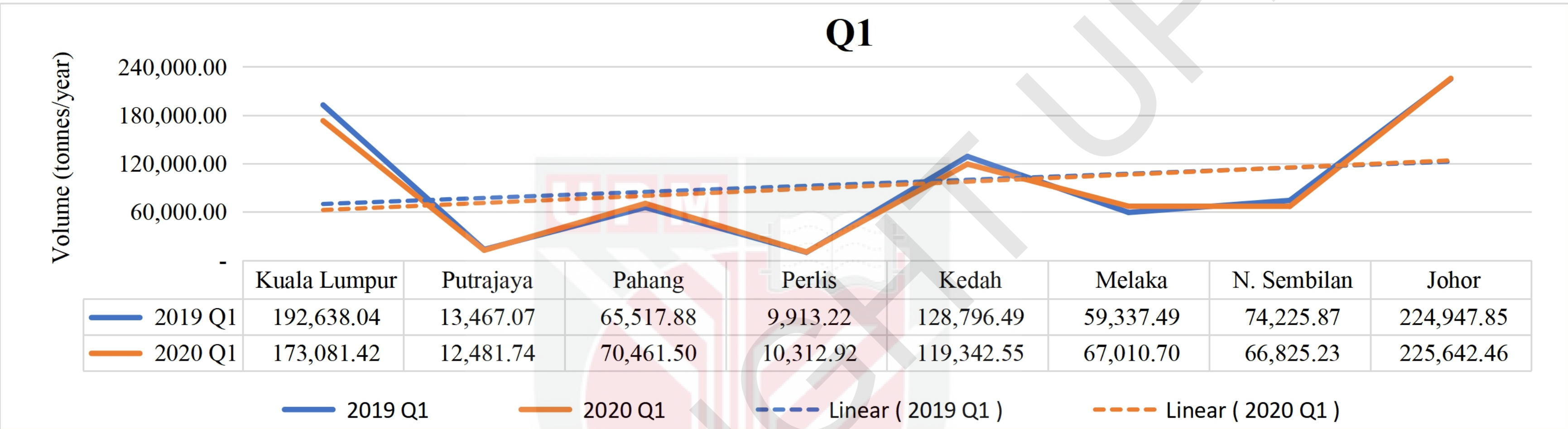
Figure 4.4: Total volume of solid waste generation by composition (tonnes/year) from 2014-2020 in Malaysia

4.2 Solid waste generation before and during MCO.

4.2.1 Comparison of total volume solid waste generation by quarter year

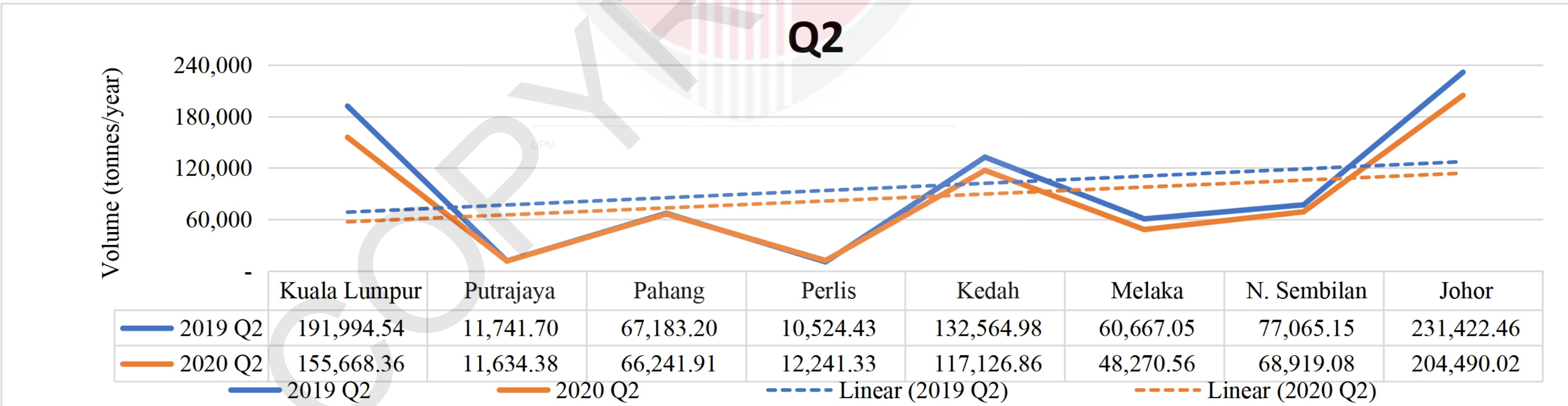
The total volume of solid waste generation before and during MCO was compared by quarter year 2019 (represent before MCO) and 2020 (during MCO).The quarter 1 (Q1) represent the total volume of waste generation from January to March, quarter 2 (Q2) from April to June, quarter 3 (Q3) from July to September and quarter 4 (Q4) from October to December.

A paired-samples t-test was performed to compare the mean of total volume of solid waste generated quarterly in all states before and during the MCO. The result reveals that, no significant difference ($p>0.05$) in total volume of solid waste generated in all states in Q1 before and during MCO ($t=0.952$, $p=0.373$). **Figure 4.5** showed only slightly reduction in the total volume of solid waste generation in Q1 during the MCO (768,843.91 tonnes/month (t/mt)) as compared to before MCO (745,158.52 t/mt). The area that showed slightly reduction was in Kuala Lumpur (173,081.42 t/mt), Putrajaya (12,481.74 t/mt), Kedah (119,342.55 t/mt) and Negeri Sembilan (66,825.23 t/mt). Meanwhile, the states that had slightly increased in the production of solid waste volume during the MCO include Pahang (70,461.50 t/mt), Perlis (10,312.92 t/mt), Melaka (67,010.70 t/mt) and Johor (225,642.46t/mt).



	Kuala Lumpur	Putrajaya	Pahang	Perlis	Kedah	Melaka	N. Sembilan	Johor
2019 Q1	192,638.04	13,467.07	65,517.88	9,913.22	128,796.49	59,337.49	74,225.87	224,947.85
2020 Q1	173,081.42	12,481.74	70,461.50	10,312.92	119,342.55	67,010.70	66,825.23	225,642.46

Figure 4.5: Total volume of solid waste for Q1 (tonnes/month) before MCO (2019) and during MCO (2020)



	Kuala Lumpur	Putrajaya	Pahang	Perlis	Kedah	Melaka	N. Sembilan	Johor
2019 Q2	191,994.54	11,741.70	67,183.20	10,524.43	132,564.98	60,667.05	77,065.15	231,422.46
2020 Q2	155,668.36	11,634.38	66,241.91	12,241.33	117,126.86	48,270.56	68,919.08	204,490.02

Figure 4.6: Total volume of solid waste for Q2 (tonnes/month) before MCO (2019) and during MCO (2020)

There is a significant difference ($p<0.05$) in volume of solid waste generated before and during MCO ($t=2.565$, $p=0.037$) in all states for Q2. **Figure 4.6** showed the total volume of solid waste in Q2 during MCO (684,592.50 tonnes/month (t/mt)) was lower compared to Q2 (783,163.51 t/mt) before MCO. The mean and standard deviation was 97,895.44 ±80,804.30 before the MCO and 85,574.06 ± 68,595.33 during the MCO.

For the Q3, the total volume of solid waste generated before and during MCO showed similar trend as there is no significant difference ($p>0.05$) in total solid waste generated in all states before and during MCO ($t=1.486$, $p=0.181$). The total volume of solid waste generated during MCO was 759,727.31 t/mt and 798,371.35 t/mt was before MCO (**Figure 4.7).**

The statistical analysis indicates that there is no significantly difference in volume of solid waste generated ($p>0.05$) before and during MCO in all states for Q4 ($t=0.322$, $p=0.181$). During MCO, the total waste volume collected for Q4 was 756,363.01 t/mt and 751,810.40 t/mt before MCO (**Figure 4.8**).

Figure 4.7: Total volume of solid waste for Q3 (tonnes/month) before MCO (2019) and during MCO (2020)

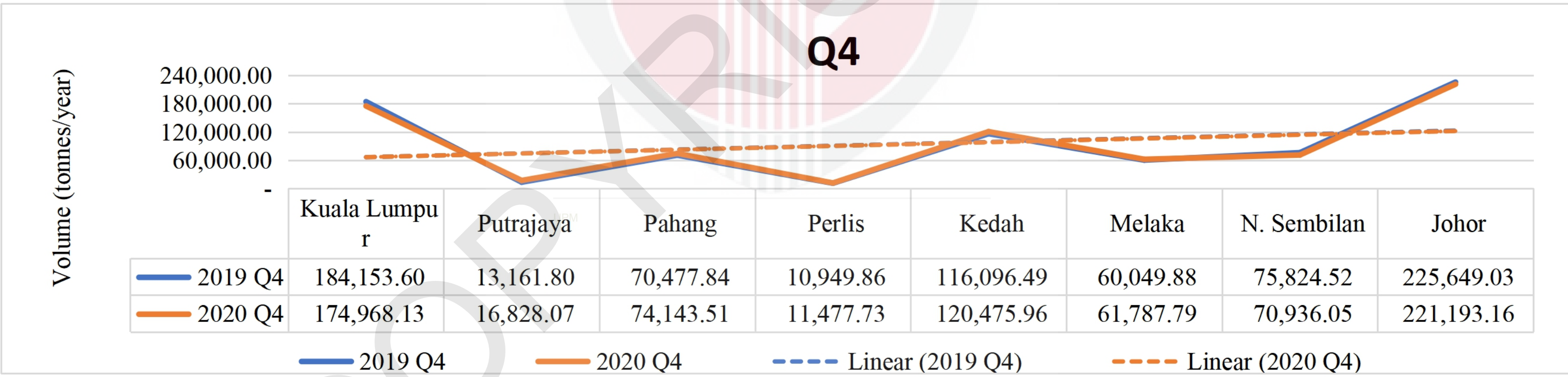


Figure 4.8: Total volume of solid waste for Q4 (tonnes/month) before MCO (2019) and during MCO (2020)

The percentage of changes in the total volume of solid waste generation during

States	Variation (%)			
	Q1	Q2	Q3	Q4
WPKL	-5.35%	-10.45%	-6.22%	-2.56%
Putrajaya	-3.80%	-88.57%	4.25%	12.23%
Pahang	3.64%	-0.71%	-1.13%	2.53%
Perlis	1.98%	7.54%	-0.93%	2.35%
Kedah	-3.81%	-6.18%	-0.91%	1.85%
Melaka	6.07%	-11.38%	-0.06%	1.43%

MCO for every quartile was shows in **Table 4.1** and in **Figure 4.9**. For every quartile (Q1 to Q4), Kuala Lumpur showed continuous reduction in the total volume of solid waste during the MCO with the highest reduction recorded in Q2 (-10.45%).

Q2 showed the highest reduction in solid waste generation during MCO (-6.72%). This is due to majority of all states had decreased in total volume of solid waste generation during MCO except for Perlis. In contrast, Q4 has the lowest reduction of solid waste generation during MCO with -0.3%. This is because majority of all states had increased in solid waste generation except for Kuala Lumpur, Negeri Sembilan and Johor.

As for overall quartile, the highest reduction of total volumes of solid waste generation during MCO was in Melaka with -11.38% during Q2 and Putrajaya attributed the lowest reduction during Q2 with -0.71%. Putrajaya also recorded with an increase waste generation in Q4 at +12.23%.

N. Sembilan	-5.25%	-5.58%	1.85%	-3.33%
Johor	0.15%	-6.18%	-3.26%	-1.00%
Max	6.07%	7.54%	4.25%	12.23%
Min	-5.35%	-11.38%	-6.22%	-3.33%

Table 4.1: The percentage of production and reduction of solid waste generation during MCO by quarter

Note: The -ve sign indicate the reduction of volume waste generation of during MCO implementation

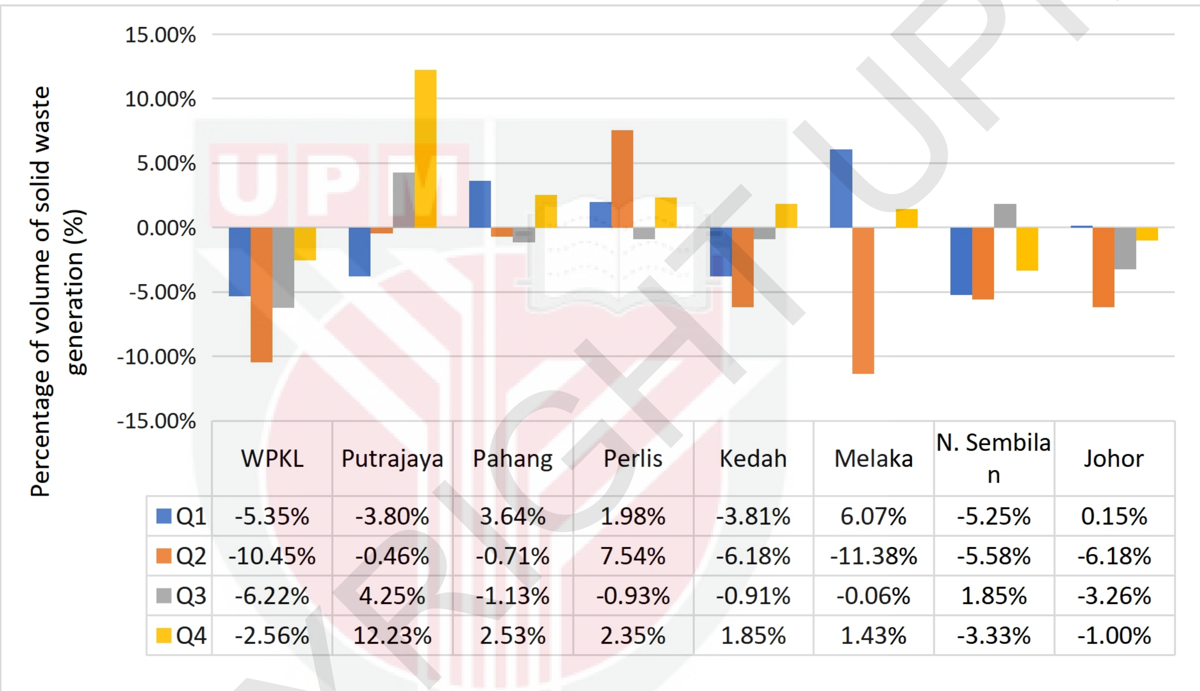


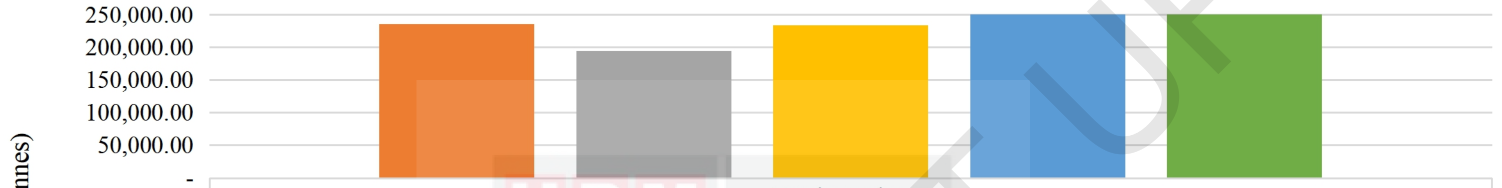
Figure 4.9: The percentage of production and reduction of solid waste generation during MCO by quarter.

4.2.2 Solid waste generation during Movement Control Order (MCO) by phases

There are 5 phases that was implemented in the first MCO imposed by government across country which are Phase 1 (March), Phase 2 (April), Phase 3 (May), Phase 4 (June), Phase 5 (average amount from July to December). Based on **Figure 4.10** Phase 4 of MCO (June) recorded the highest solid waste generation (88,578.52

tonnes) with the mean ± SD of 32,000.93 tonnes ±25,187.32 tonnes. Phase 2 was recorded with the lowest volume of waste (194,428.42 tonnes) with a mean ±SD of 24,303.55 tonnes ±19,410.66 tonnes.

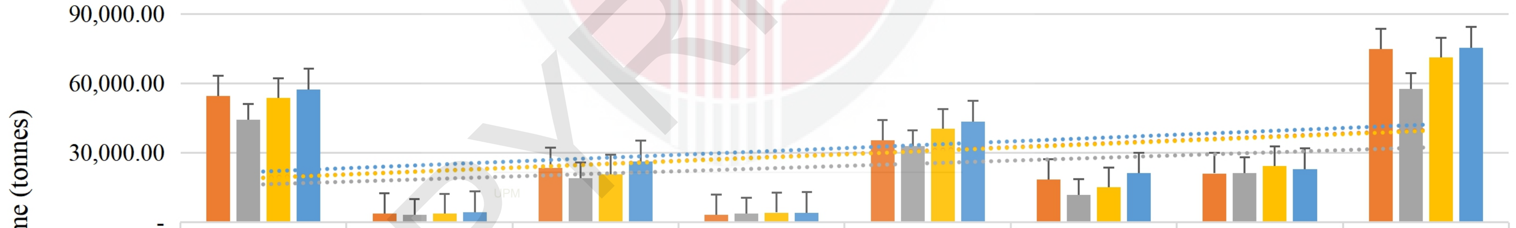
Figure 4.11 shows the waste volume from Phase 1 to Phase 5 by states and Johor contributed the highest total amount of solid waste generated during MCO which is 354,215.57 tonnes with the mean ± SD of 70,843.1124 tonnes ± 7,564.74tonnes per phase. Putrajaya was recorded with the lowest amount of solid waste generated from Phase 1 to Phase 5 which in total of 20,689.92 tonnes and the mean ± SD of 4,137.98 tonnes ± 673.92 tonnes per phase.



	Total per phases
Phase 1	235,836.87
Phase 2	194,428.42
Phase 3	234,156.68
Phase 4	256,007.40
Phase 5	251,922.95

Phase 1 Phase 2 Phase 3 Phase 4 Phase 5

Figure 4.10: Total volume of solid waste generation (tonnes) during MCO by phases.



	WPKL	Putrajaya	Pahang	Perlis	Kedah	Melaka	N. Sembilan	Johor
Phase 1	54,559.55	3,940.79	23,505.35	3,424.16	35,614.92	18,529.32	21,218.65	75,044.13
Phase 2	44,285.18	3,337.58	19,036.21	3,831.46	33,071.19	11,843.31	21,386.92	57,636.58
Phase 3	53,864.38	3,846.06	20,808.01	4,269.77	40,441.71	15,119.11	24,473.49	71,334.15
Phase 4	57,518.80	4,450.74	26,397.69	4,140.10	43,613.96	21,308.14	23,058.68	75,519.29

Phase 1 Phase 2 Phase 3 Phase 4 Linear (Phase 1) Linear (Phase 2) Linear (Phase 3) Linear (Phase 4)

Figure 4.11: Total volume of solid waste generation (tonnes) during MCO hy states

4.3 The environmental impacts of landfilling before and during MCO

4.3.1 Greenhouse gases (GHG) emissions (CH_4, CO_2)

Figure 4.12 shows the comparison of estimated total methane (CH_4) emission by landfilled domestic waste generation before (represent by year 2019) and during MCO (represent by year 2020). The one-way Anova analysis, indicated that the estimated total direct emissions of CH_4 in landfills was significantly reduced ($p<0.05$) during MCO in all states ($F=1413.67$, $p< 0.001$). From the figure, the amount of methane had reduced from 110,805.67 tonnes before MCO to 104,904.59 tonnes during MCO.

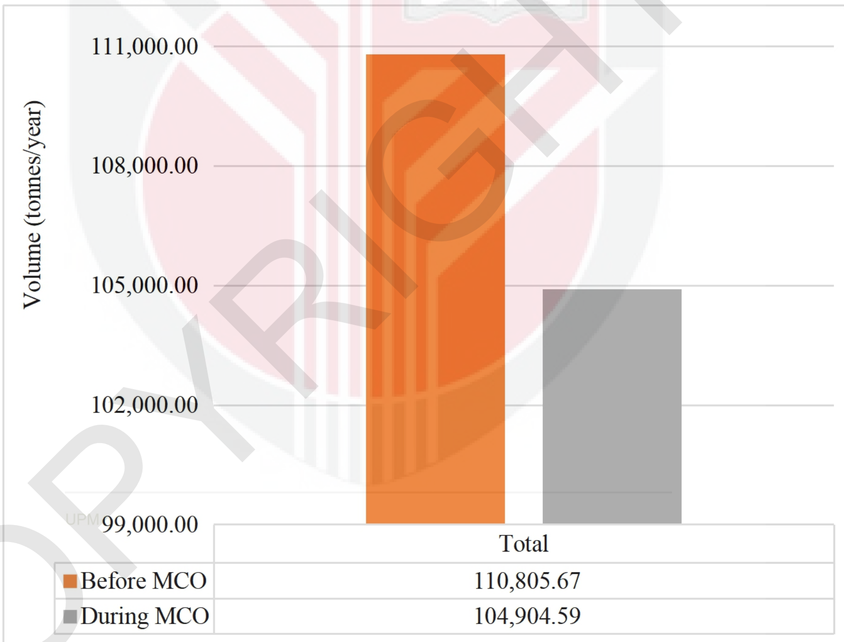


Figure 4.12 Total volume of methane emission (tonnes/year) before and during MCO

Figure 4.13 shows the total of Carbon dioxide equivalent (CO2-eq) by landfilled domestic waste generation before MCO (represent by year 2019) and during MCO (represent by year 2020). The data analysis indicated that the estimated of total direct emissions of CO2-eq in landfills was reduced ($p<0.05$) during MCO in all states

(F=1413.67, p< 0.001). The CO2-eq reduced from 2,770,141.71 tonnes before MCO to 2,622,614.67 tonnes during MCO.

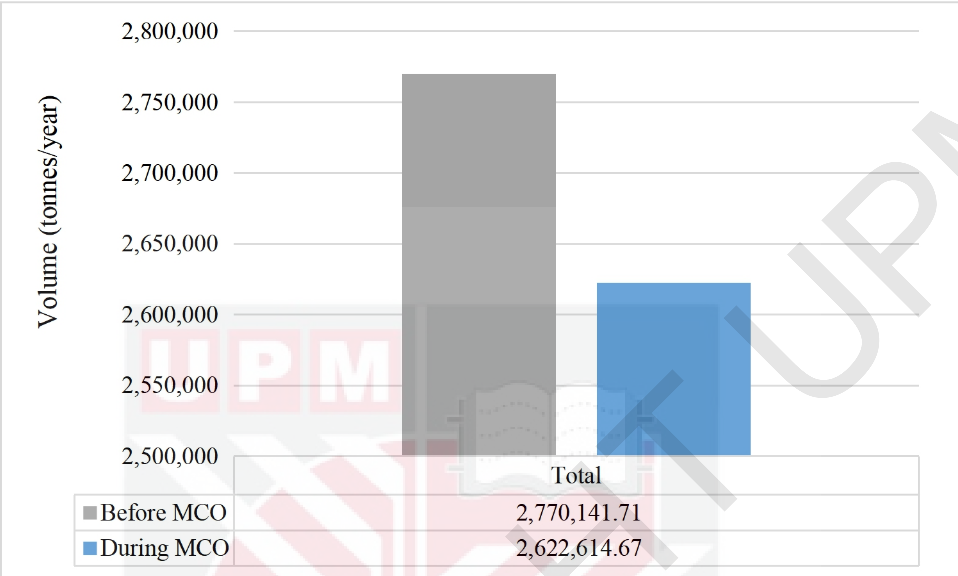
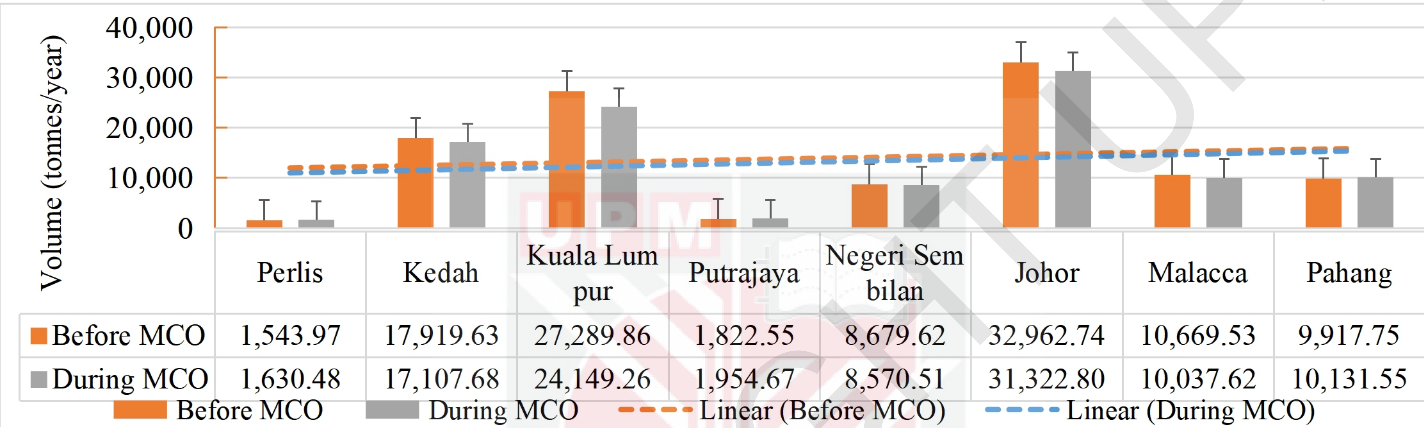


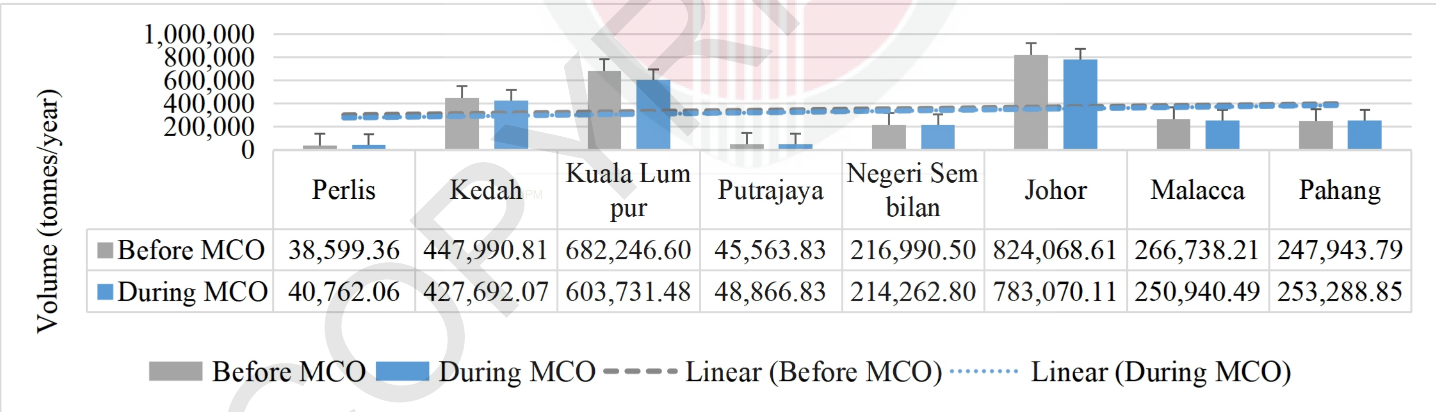
Figure 4.13 Total volume of CO_2-eq emission (tonnes/year) before and during MCO

Figure 4.14 and **Figure 4.15** showed the estimated CH_4 emissions before and during MCO by the states. Based on the data reported that, the highest CH_4 emission during MCO was generated by Johor (31,554.38 t/yr), followed by Kuala Lumpur (24,223.13 t/yr.) and Kedah (17,170.20 t/yr.). Whereas, the lowest CH4 emission during MCO was in Perlis (1,683.76 t/yr.) and Putrajaya (2,006.29 t/yr.). A similar trend was observed for CO2-eq emission. The highest CO2-eq emission was Johor (788,859.39 t/yr.), followed by Kuala Lumpur (605,578.22 t/yr.) and Kedah (429,255.08 t/yr.) Perlis and Putrajaya was the lowest contributor to CO2-eq emission with (42,093.92 t/yr.) and (605,578.22 t/yr.)



	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang
Before MCO	1,543.97	17,919.63	27,289.86	1,822.55	8,679.62	32,962.74	10,669.53	9,917.75
During MCO	1,630.48	17,107.68	24,149.26	1,954.67	8,570.51	31,322.80	10,037.62	10,131.55

Figure 4.14: Total volume of methane emission (tonnes/year) before and during MCO by states



	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang
Before MCO	38,599.36	447,990.81	682,246.60	45,563.83	216,990.50	824,068.61	266,738.21	247,943.79
During MCO	40,762.06	427,692.07	603,731.48	48,866.83	214,262.80	783,070.11	250,940.49	253,288.85

Figure 4.15: Total volume of CO2-eq emission (tonnes/year) before and during MCO by states

4.3.2 Leachate production

Figure 4.16 showed the estimated leachate production in landfills (m^3) per year before MCO (represent year 2019) and during MCO (represent year 2020). The total production of leachate in landfills had significantly reduced ($p<0.05$) during MCO ($F=1413.67$, $p<0.0001$). The amount of leachate production had decreased from 536,571.87 m^3/yr before MCO to 507,996.13 m^3/yr during MCO.

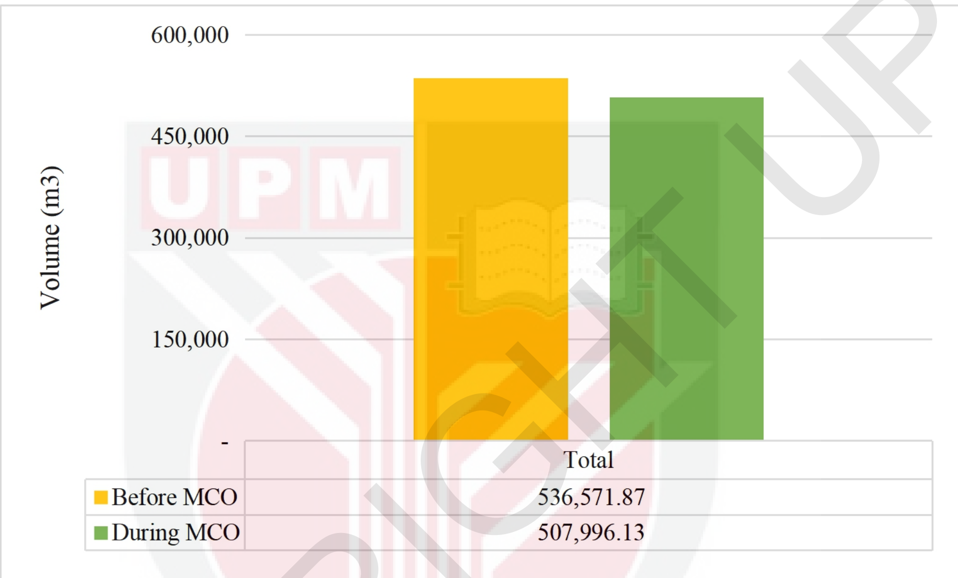
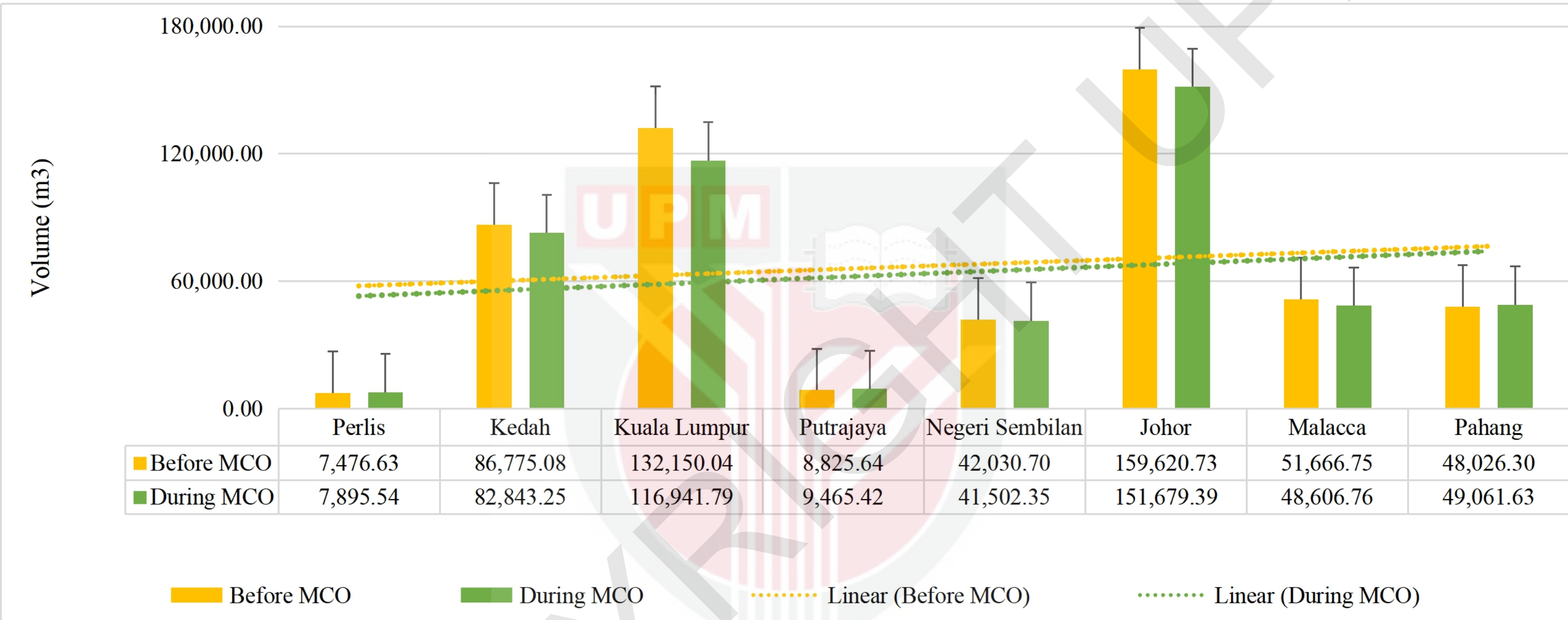


Figure 4.16: The estimated leachate production (m^3 /yr) before and during MCO

The highest estimated production of leachate during MCO was in Johor (152,800.76 m^3/yr) compared to other states due to Johor generated high volume of solid waste and disposed to the landfills. Kuala Lumpur (117,299.50 m^3/yr) and Kedah (83,146.00 m^3/yr) also generated high production of leachate during MCO after Johor. Whereas, the lowest of estimated production of leachate during MCO was in Perlis (8,153.52 m^3/yr) and Putrajaya (9,715.37 m^3/yr) as shown in **Figure 4.17**.



	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang
Before MCO	7,476.63	86,775.08	132,150.04	8,825.64	42,030.70	159,620.73	51,666.75	48,026.30
During MCO	7,895.54	82,843.25	116,941.79	9,465.42	41,502.35	151,679.39	48,606.76	49,061.63

Figure 4.17: The estimated leachate production (m^3/yr) before and during MCO by the states

4.4 The health impact of NMVOC emissions before and during MCO

Non-methane volatile organic compounds (NMVOC) emissions were used to calculate the health risk. There are five types of NMVOC compounds that were selected on this study for health risk estimation which include Halogenated, oxygenated, sulphur, aromatic, and alkane. The non-carcinogenic and carcinogenic risks were used to calculate the health risk.

4.4.1 Halogenated compounds emission

Figure 4.18 shows the total direct emission of the 23 selected halogenated compounds for before (represent year 2019) and during MCO (represent year 2020). Overall, the implementation of MCO had reduced the total direct emission of halogenated compounds in all the states compared to before MCO. From data analysis, Dichlorodifluoromethane was the highest halogenated compound emitted by all the states during MCO (1.26E+002 m^3/yr) but low compared to before MCO (1.33E+00 m^3/yr). This followed by dichloromethane (1.15E+00 m^3/yr.) and vinyl chloride (5.89E-01 m^3/yr.). The lowest estimated direct emission of halogenated compounds during MCO was ethylene dibromide (8.02E-05 m^3/yr) from before MCO. (8.47E-05 m^3/yr.).

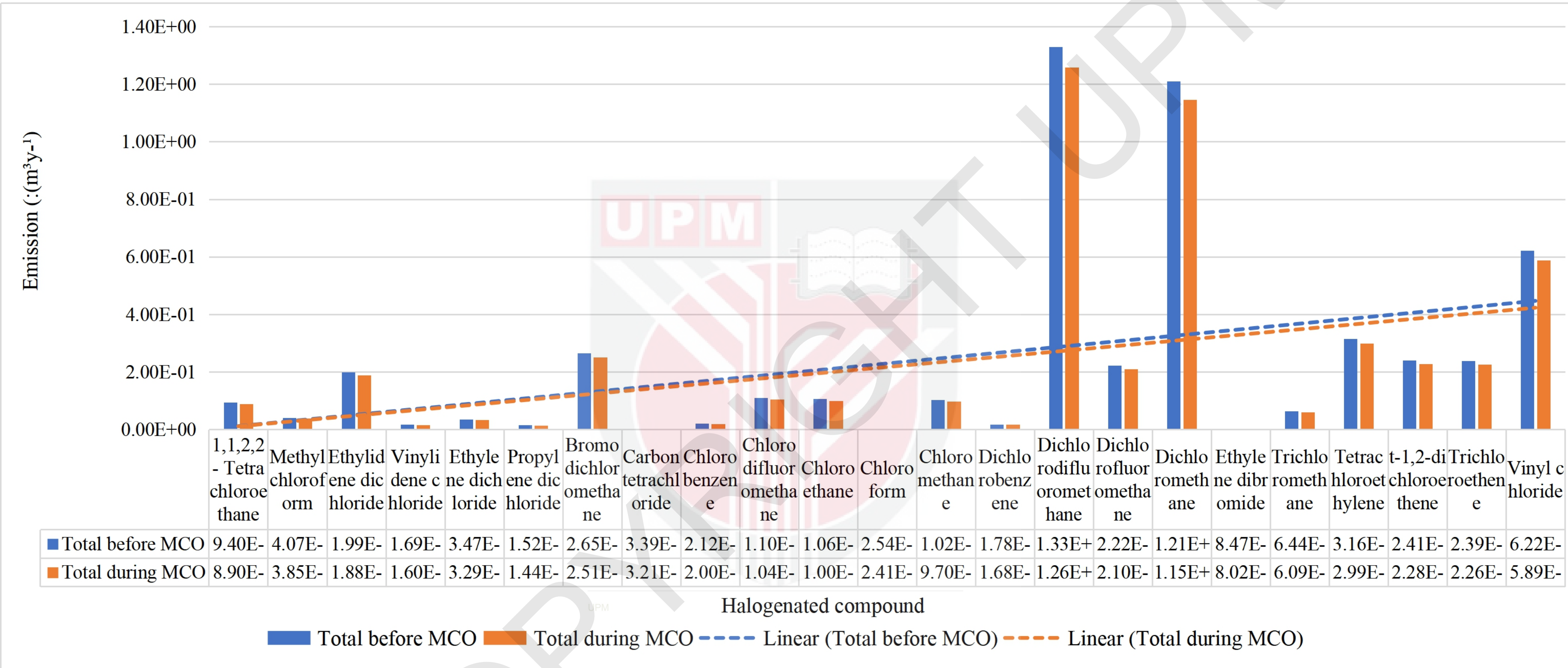
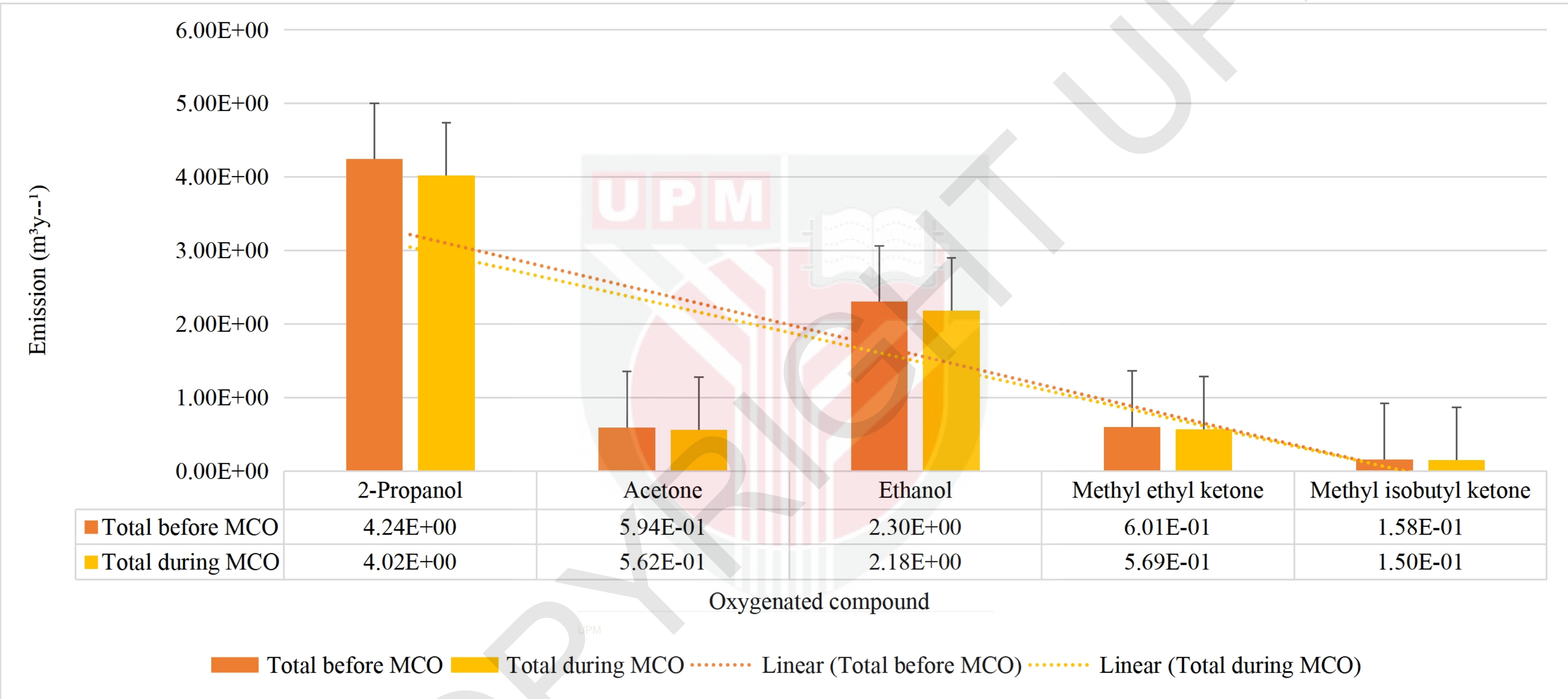


Figure 4.18: The total emission of halogenated compounds (m³y-¹) before and during MCO

4.4.2 Oxygenated compounds emission

Figure 4.19 shows the total direct emission of the oxygenated compounds for before MCO (represent year 2019) and during MCO (represent 2020). Overall, the implementation of MCO had reduced the total direct emission of oxygenated compounds in all the states from before MCO during MCO. From data analysis, 2-propanol was the highest oxygenated compound emitted by all the states during MCO (4.02E+00 m^3/yr) but low compared to before MCO (4.24E+00 m^3/yr). This followed by ethanol (2.18E+00 m^3/yr.). The lowest estimated direct emission of oxygenated compounds during MCO was methyl isobutyl ketone 1.50E-01 m^3/yr.



	2-Propanol	Acetone	Ethanol	Methyl ethyl ketone	Methyl isobutyl ketone
Total before MCO	4.24E+00	5.94E-01	2.30E+00	6.01E-01	1.58E-01
Total during MCO	4.02E+00	5.62E-01	2.18E+00	5.69E-01	1.50E-01

Figure 4.19: The total emission of oxygenated compounds (m^3y^{-1}) before and during MCO

4.4.3 Sulphur compounds emission

Figure 4.20 shows the total direct emission of the sulphur compounds for before MCO (represent year 2019) and during MCO (represent year 2020). Overall, the implementation of MCO had reduced the total direct emission of sulphur compounds in all the states from before MCO to during MCO. From data analysis, Hydrogen sulfide was the highest sulphur compound emitted by all the states during MCO (2.85E+00 m^3/yr) but low compared to before MCO (3.01E+00 m^3/yr). This followed by dimethyl sulfide (6.27E-01 m^3/yr.). The lowest emission compound during MCO was carbonyl sulfide with 3.93E-02 m^3/yr emission.

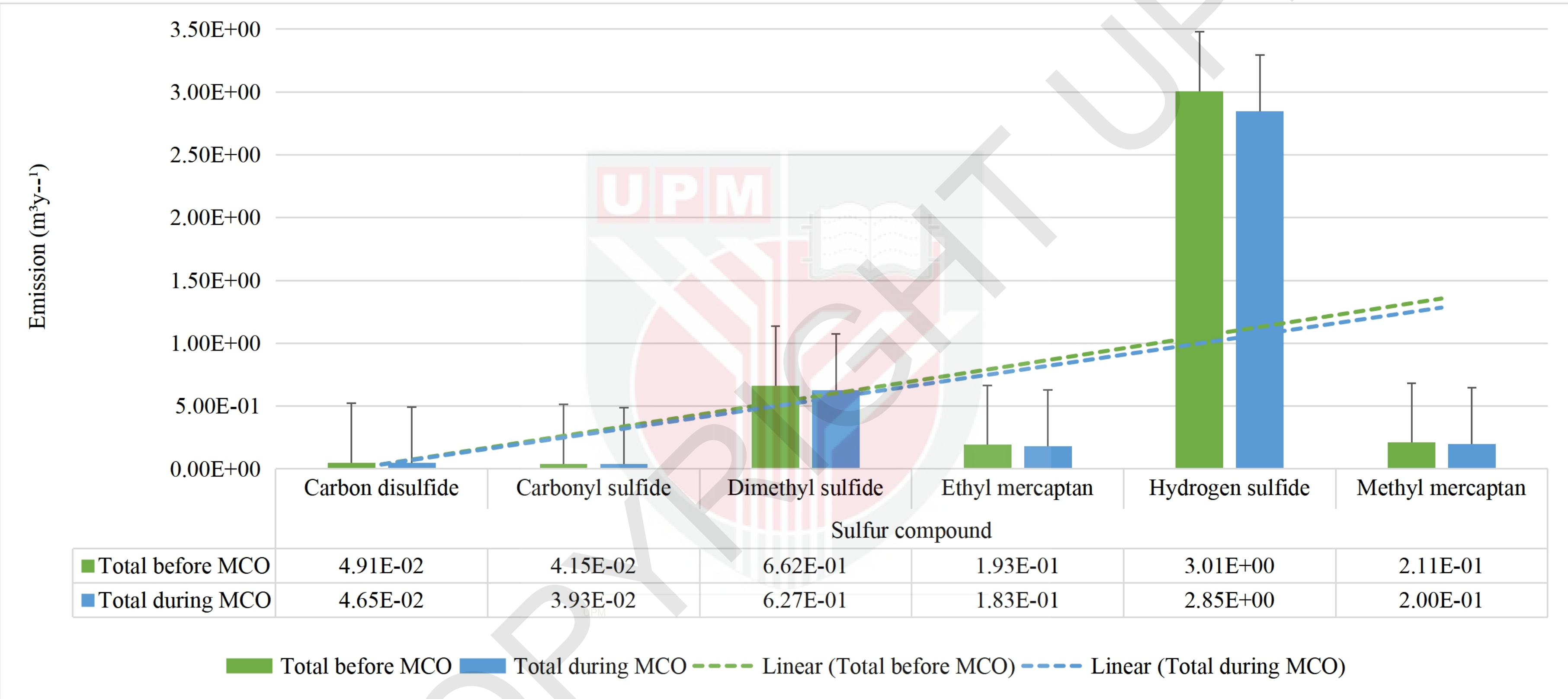


Figure 4.20: The total emission of sulphur compounds (m^3y^{-1}) before and during MCO

4.4.4 Aromatic compounds emission

Figure 4.21 shows the total direct emission of the aromatic compounds for before MCO (represent year 2019) and during MCO (represent year 2020). Overall, the implementation of MCO had decreased the total direct emission of aromatic compounds in all the states from before MCO to during MCO. From data analysis xylenes contributed the highest emission during MCO (9.70E-01 m^3/yr.) but low compared to before MCO (1.02E+00 m^3/yr.). Whereas, the lowest emission for before and during MCO contributed by ethylbenzene 3.90E-01 m^3/yr for before MCO and 3.70E-01 m^3/yr for during MCO.

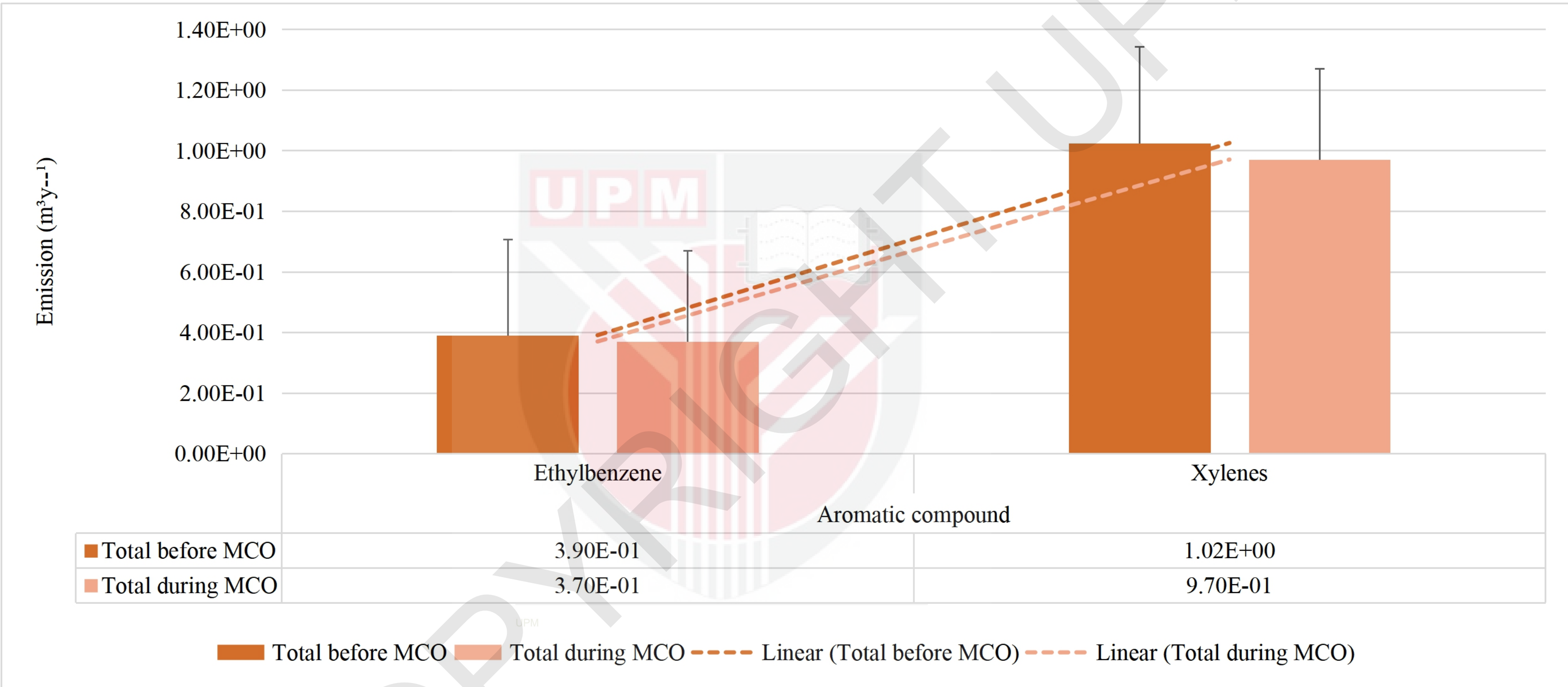


Figure 4.21: The total emission of aromatic compounds (m^3y^{-1}) before and during MCO

4.4.5 Alkane compounds emission

Figure 4.22 shows the total direct emission of the alkane compounds for before MCO (represent year 2019) and during MCO (represent year 2020). Overall, the implementation of MCO had reduced the total direct emission of alkane compounds in all the states from before MCO to during MCO. From the figure, Propane was the highest alkanes compounds with the direct emission (8.90E-01 m3/yr) during MCO but low compared to before MCO (9.40E-01 m3/yr). This is followed by hexane (5.27E-01 m3/yr) and butane (4.03E-01 m3/yr). The lowest emission during MCO contributed by pentane with 2.64E-01 m3/yr.

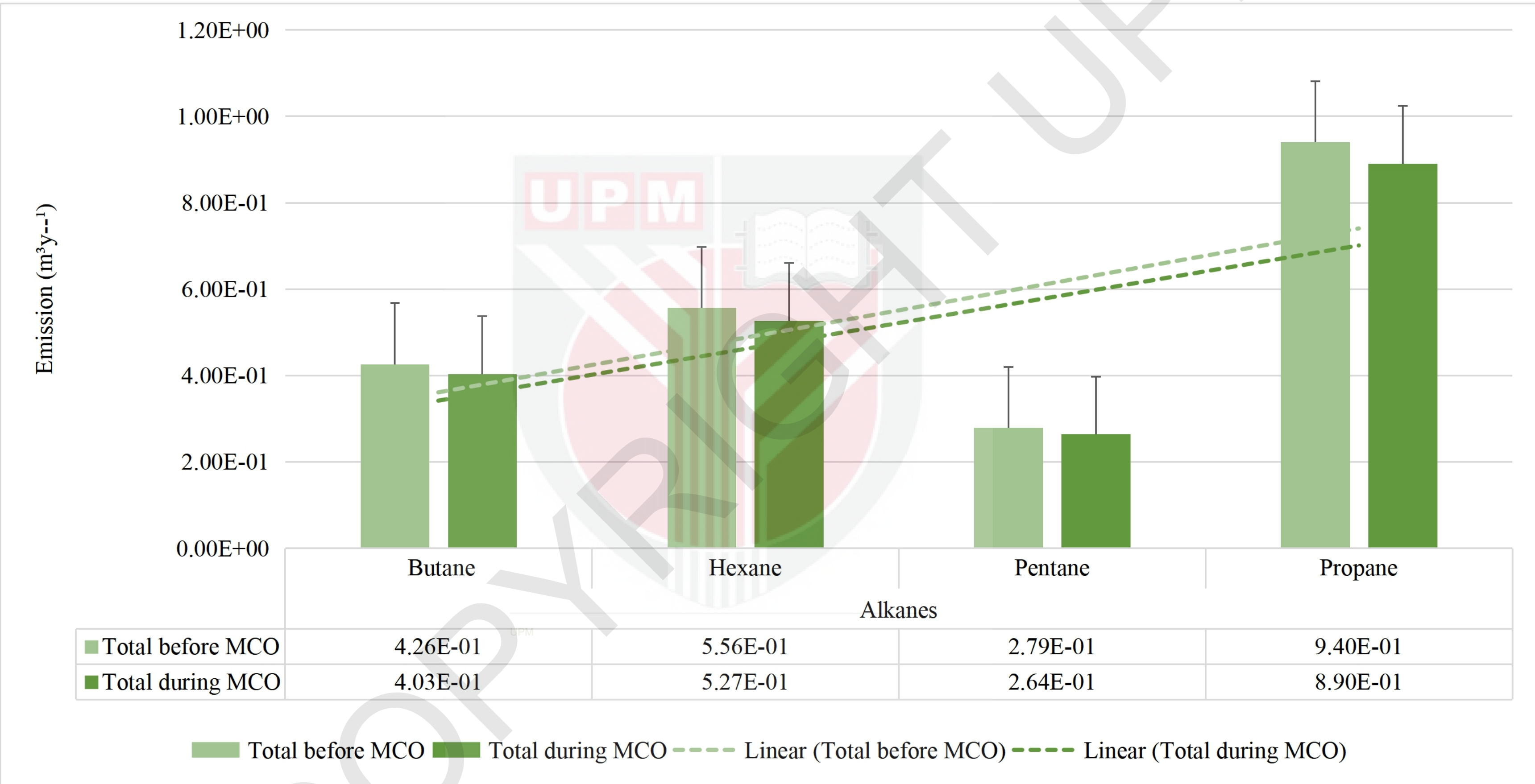


Figure 4.22: The total emission of alkane compounds (m^3y^{-1}) before and during MCO

4.4.6 Non-carcinogenic risk

Table 4.2 shows the cumulative non-carcinogenic risk hazard quotient (HQ) of inhalation exposure to non-methane volatile organic compounds (NMOVC) before MCO (represent year 2019) and during implementation of MCO (represent year 2020) generated by landfilled domestic waste. There were three groups of population for (child, adult woman and adult man) for estimation of the health risk which was based on the inhalation exposure towards estimated total concentration of NMVOC by all states that was calculated in this study. Besides, the twenty-one compounds of NMVOC have been selected and assessed for non- carcinogenic risk based on the existing data of reference concentration for inhalation exposure (Rfc). Hazard index (HI) above 1 (HI >1) indicates a non-carcinogenic risk to human health.

Overall, the analysis showed that the HI values in majority of the groups were in acceptable limit from the estimated emission in landfill by domestic waste representing non-carcinogenic health risk to the residents in the study area for before and during MCO implementation.

Table 4.2: The range of Hazard Quotient (HQ) for NMVOC emission for man, woman by states before and during MCO

States	Range of Hazard quotient (HQ)					
	Before MCO implementation			During MCO implementation		
	Man	Woman	Children	Man	Woman	Children
Perlis	1.06E-11 - 5.75E-07	1.10E-11 -5.98E-07	1.45E-11 -7.85E-07	1.12E-11 -6.07E-07	1.16E-11 -6.31E-07	1.53E-11 -8.29E-07
Kedah	4.53E-11 - 2.45E-06	4.71E-11 - 2.55E-06	6.18E-11 - 3.35E-06	1.17E-10 - 6.37E-06	1.22E-10 - 6.63E-06	1.60E-10 - 8.70E-06
Kuala Lumpur	1.87E-10 – 1.02E-05	1.95E-10 – 1.06E-05	2.56E-10 – 1.39E-05	1.66E-10 – 8.99E-06	1.72E-10 – 9.35E-06	2.26E-10 – 1.23E-05
Putrajaya	4.60E-12 – 2.50E-07	4.79E-12 – 2.60E-07	6.28E-12 – 3.41E-07	1.34E-11 – 7.28E-07	1.40E-11 –7.57E-07	1.83E-11 – 9.94E-07
Negeri Sembilan	2.19E-11 – 1.19E-06	2.28E-11 – 1.24E-06	2.99E-11 – 1.62E-06	5.89E-11 – 3.19E-06	6.12E-11 – 3.32E-06	8.03E-11 – 4.36E-06
Johor	2.26E-10 – 1.23E-05	2.35E-10 – 1.28E-05	3.09E-10 – 1.68E-05	2.15E-10 – 1.17E-05	2.24E-10 – 1.21E-05	2.94E-10 – 1.59E-05
Malacca	2.70E-11 – 1.46E-06	2.80E-11 – 1.52E-06	3.68E-11 – 2.00E-06	6.89E-11 – 3.74E-06	7.17E-11 – 3.89E-06	9.41E-11 – 5.10E-06
Pahang	6.81E-11 - 3.69E-06	7.08E-11 - 3.84E-06	9.30E-11 - 5.04E-06	6.96E-11 - 3.77E-06	7.24E-11 - 3.92E-06	9.50E-11 - 5.15E-06

Note: Potential health risks through inhalation exposure were estimated for different inhalation rate (15m^3/day-child; 23m^3/day-Adult man; 21m^3/day-Adult woman (WHO, 1994; WHO, 1999)), lifetime expectancy (Female: 77.6 and Male: 72.7 (DOSM, 2018)), and average body weight (Child: 31.8 kg (U.S EPA, 2009); Adult man: 66.56kg; and Adult woman 58.44 (Azmi et al., 2009)

4.4.7 Carcinogenic risk

Table 4.3 shows the cumulative carcinogenic risk of lifetime cancer risk (LCR) for the inhalation exposure to Non-Methane Volatile Organic compounds (NMOVC) before MCO (represent year 2019) and during implementation of MCO (represent year 2020) generated from landfilled domestic waste. The risks were estimated for three groups (i.e., child, woman, and man) based on the estimated total concentration of NMVOC emitted by all states. Besides, eight compounds from halogenated category compound have been selected and assessed for carcinogenic risk based on the existing data of unit risk factor (URF). A lifetime cancer risk (LCR) with a value of more than 1.0E-04 and 1.0E-03 indicates a carcinogenic risk to human health. Overall, the analysis showed that the LCR values in majority of the groups were in acceptable limit for before and during MCO implementation.

Table 4.3: The range of Life time cancer risk (LCR) for NMVOC emission for man, woman by states before and during MCO

States	Range of Life time cancer risk (LCR)					
	Before MCO implementation			During MCO implementation		
	Man	Woman	Children	Man	Woman	Children
Perlis	2.69E-21 -7.25E-18	2.63E-21 - 7.07E-18	2.67E-20 -7.19E-17	2.84E-21 - 7.65E-18	2.77E-21 - 7.46E-18	2.82E-20 - 7.59E-17
Kedah	3.13E-20 - 8.41E-17	3.05E-20 - 8.20E-17	3.10E-19 - 8.35E-16	3.13E-20 - 8.41E-17	3.05E-20 - 8.20E-17	3.10E-19 - 8.35E-16
Kuala Lumpur	4.76E-20 - 1.28E-16	4.64E-20 - 1.25E-16	4.72E-19 - 1.27E-15	4.21E-20 - 1.13E-16	4.11E-20 - 1.11E-16	4.18E-19 - 1.12E-15
Putrajaya	3.18E-21 - 8.55E-18	3.10E-21 - 8.34E-18	3.15E-20 - 8.49E-17	3.41E-21 - 9.17E-18	3.32E-21 -8.94E-18	3.38E-20 - 9.10E-17
Negeri Sembilan	1.51E-20 - 4.07E-17	1.48E-20 - 3.97E-17	1.50E-19 - 4.04E-16	1.49E-20 - 4.02E-17	1.46E-20 - 3.92E-17	1.48E-19 - 3.99E-16
Johor	5.75E-20 - 1.55E-16	5.60E-20 - 1.51E-16	5.70E-19 - 1.54E-15	5.46E-20 - 1.47E-16	5.33E-20 - 1.43E-16	5.42E-19 - 1.46E-15
Malacca	1.86E-20 - 5.01E-17	1.81E-20 - 4.88E-17	1.85E-19 - 4.97E-16	1.75E-20 - 4.71E-17	1.71E-20 - 4.59E-17	1.74E-19 - 4.68E-16
Pahang	1.73E-20 - 4.66E-17	1.69E-20 - 4.54E-17	1.72E-19 - 4.62E-16	1.77E-20 - 4.76E-17	1.72E-20 - 4.64E-17	1.75E-19 - 4.72E-16

Note: Potential health risks through inhalation exposure were estimated for different inhalation rate (15m^3/day-child; 23m^3/day-Adult man; 21m^3/day-Adult woman (WHO, 1994; WHO, 1999)), lifetime expectancy (Female: 77.6 and Male: 72.7 (DOSM, 2018)), and average body weight (Child: 31.8 kg (U.S EPA, 2009); Adult man: 66.56kg; and Adult woman 58.44 (Azmi et al., 2009)

CHAPTER 5

DISCUSSION

5.1 The volume of Municipal Solid Waste (MSW) generation in Malaysia from year 2014 to 2020.

The study reported that the solid waste generation in Malaysia from 2014 to 2020 had decreased over the years. This can be seen through available data from SWCorp in Johor, Kuala Lumpur, Negeri Sembilan, Putrajaya, Pahang, Perlis, Kedah and Malacca from the past years. These states implemented the Solid Waste and Public Cleansing and Management 2007 (Act 672). Findings from Rangga et al. (2019) reported that, since the enforcement of Act 672 from 2007, a declined pattern of landfilled domestic waste volume from 2014 to 2018 in Kuala Lumpur, Pahang, Perlis and Malacca due to waste segregation scheme implementation. This is in line with the objective of Act 672 which is to increase the quality of collection, transportation, treatment, and disposal services, to safeguard the environment and people, to standardise solid waste management and public cleansing services, and to ensure effective solid waste management throughout the country (Yiing & Latifah, 2017). Besides, according to Act 672 (2007), a fine not exceeding one thousand ringgit will be imposed if a person failed to comply with subsection 74 which eventually might encourage the households to participate in activity waste separation at source (Rangga et al., 2019).

Furthermore, from the result reveals that the volume of domestic waste collected was high compared to other type of waste composition mainly because of domestic waste is the main contributor to the total volume of waste produced in Malaysia as well as other developed countries such as Singapore, Germany, and Austria (Pickin et al.,2018; Jaron & Kosman, 2018; Ministry of the Environment and Water Resources, 2014; Rangga et al, 2019). Every year domestic waste is produced with more than 90% and dumped in landfills (JPSPN, 2013; Jain, 2017). In addition, households are the highest producer of domestic waste in Malaysia as reported by JPSN in 2013 and 80% to 90% of domestic waste were sent to the landfill for disposal (JPSPN, 2013).

However, from this study it showed that different states have different volumes of waste generated per year. Johor and Kuala Lumpur were the top producers of waste generation in our country whereas Perlis was the least producer of solid waste. There are few factors that can contribute to the solid waste generation in every state. The factors might include urbanization, economic development and population growth (Hoornweg & Perinaz, 2012). According to DOSM (2021), 72.3% of Malaysia's total Gross Domestic Product (GDP) per capita were contributed by Johor and Kuala Lumpur which was among the six states that contributed in 2019. Furthermore, according to Hasan (2012), HDI is one of the most important indicators to measure economic development. All eight states were indexed as having a very high HDI (>0.8) except putrajaya from the UNDP report in 2019. This explains why Johor and Kuala Lumpur generate high solid waste and study by Rangga et al. (2019) reported that states with a very high human development index (VHDI) produced a large amount of landfill and segregate waste.

Southern and Central regions which consist of states Johor, Malacca, Kuala Lumpur, Putrajaya and Negeri Sembilan were the highest regions that generated solid waste compared to Northern and East regions. This possibly related to the rapid urbanization factor and population growth in the central and south region. According to the Zamani et al. (2019), there is a significant relationship between MSW generation with the population growth as almost 20% or 3.3% increase of total solid waste generated annually within six years in Malaysia. Population of Johor and Kuala Lumpur are 1,045,000 million and 8,211,000 million respectively in 2021. Besides, according to a study conducted by Zainura (2016), the states of Kuala Lumpur, Malacca, and Selangor produce the greatest percentages of municipal solid waste (MSW) in Malaysia due to rapid urbanisation and economic growth and they are anticipated to continue to generate substantial MSM in the future.

5.2 The comparison of the Municipal Solid Waste (MSW) generation in Malaysia by states before and during MCO.

Overall, the study reported that there was no significant difference in the volume of generated waste between Quarter 1 (Q1), Quarter 3 (Q3) and Quarter 4 (Q4) before and during MCO. Q1, Q3 and Q4 show similar trends of only minimal changes in volume reduction during MCO between the states except Q2. This can be seen by the reduction percentage in Q1 which is only 1.56% during MCO.

However, there is a significant difference in the volume of generated waste before and during MCO in Q2 with the total of 6.72% reduction in the volume of solid waste generated. The possible factor leading to these findings is that in Q2, people remained locked down at their home with families due to stay-at-home order and rigid restrictions. People are prohibited to travel from one location to another within any infected local area unless for permitted reasons. According to Prevention and Control of Infectious Disease Act (Act 342) (1988), Any person that failed to comply with the order will be fined a maximum of RM1,000 or imprisoned for a maximum of six months, or both. Other than that, MCO had imposed restrictions on travel for more than 10 kilometres per individual. This makes people only subjected to shop groceries around their house areas rather than shopping malls in distant areas. According to Regina et al. (2021), restriction in travel among the residents had declined the percentage of persons purchasing food sources except online shopping.

Besides, only two people per household are now allowed to head out to purchase groceries at nearby supermarkets or grocery stores which previously limited to one person if the second person is from family members (Free Malaysia Today, 2020;

Tharanya, 2021). According to a recent research by Tan and Siti (2020), the percentage of Malaysians in Penang who prefer to shop for groceries "1-2 times each week" dropped from 68% to 66% under MCO, forcing individuals to shop only when necessary. Other strict measures that were enforced during earliest MCO implementation included prohibition of buffets activity at the hotels, replacement of dine-in with only take-aways which might be a causal factor of the solid waste reduction in Q2. Household waste is the largest source of Municipal solid waste in Malaysia followed by commercial and institutional waste, the sources of MSW in Malaysia vary depending on city size and economic conditions for each local authority area (Samsudin & Mat Don, 2013). Due to that, as the temporary shutdown of hotel buffets, there is a reduction of solid waste during MCO that comes from the commercial sector. Other countries such as the United States also had temporarily closed the hotel buffet due to safety concerns and may not be able to reopen once the COVID-19 situation has passed (Janet, 2020). Besides, according to Martin (2020) in article reported in The Star, an initial survey done by The Malaysia Singapore Coffeeshop Proprietors' General Association (MSCPGA) and Malaysian Muslim Restaurant Owners Association (Presma), over 2,000 coffee shops and mamak restaurants in the country have shut down permanently and 80% of their members ceased doing business since the implementation of the movement control order (MCO) in March.

Whereas in Q3 and Q4 was the period of Recovery Movement Control Order (RMCO) and Conditional Movement Control Order (CMCO) was implemented in several states in Malaysia. Q3 and Q4 was reported in this study that there is no significant difference in before and during MCO. This is because there are only slight changes in the increase of volume solid waste generated in all states before and during MCO with 2.48% reduction in Q3 followed by 0.3% in Q4. Yet, Q3 and Q4 had shown an increase of solid waste generated after Q2. This is due to MCO restrictions had lifted up with more flexibility and permitted activities. The business operation and economic sectors started to reopen where they contributed to the waste generated. For example, all eateries in Malaysia including food delivery services are allowed by the government to operate until 10 pm as the federal government agreed to remove the limitations on eateries, hawkers, market and by extending Conditional MCO until June 9, 2020 (Bernama, 2020). Besides, household waste had shown a spike during stay-at-home compliance because of online purchasing and online food delivery activities (Teoh, 2020). All of these could be the reasons for the inclined trend in volume of solid waste generated during Q3 and Q4.

The lowest reduction in volume of solid waste was during MCO phase 2, this is due to the stricter rules. MCO phase 2 was implemented from April 1 until 14 April with stricter measures announced by Malaysian government with non-essential businesses not operated. Although the eateries, market and market were allowed to operate from 8am to 8pm, the authorities advised the public to opt for delivery services for purchasing meals and groceries. Separately, Enhanced Movement Control Order (EMCO) was imposed to the areas that have high clusters of COVID-19 disease for 14 days. During the contained period, the residents relied only on food supplies from the government. According to Bernama (2020), Selangor Exco had distributed the basic food supplies during 14 days for all residents in Kampung Dato' Ibrahim Majid and Bandar Baharu Dato' Ibrahim Majid and Simpang Renggam. Besides, the temporary closure of business operations during MCO in Malaysia had eventually declined the Malaysia's Industrial Production Index (IPI) at -4.9% year on year that led to reduction of solid waste in Malaysia (Heikal et al., 2020). Meanwhile, the highest waste generated was during MCO phase 3. The period was from April 29 until May 3, 2020. During this time, the MCO was lifted up with less restriction and economic and human activities were returned back to normal. Nithi Nesadurai, a president of Environmental Protection Society Malaysia had spoken about the prediction of a rising economy and human activities to pent-up demand during the past several weeks (The Star, 2020). This is because, according to The Star (2020), Faizal Parish, director of the Global Environment Centre, many sectors may double up operations to produce extra revenue to compensate for revenue lost during the MCO period. However, due to few Small and Medium Enterprises (SMEs) may have been substantially affected by MCO implementation, the economic activities will be carried on in a more gradual manner (Teoh, 2020). This explained why total volume of waste generated during MCO phase 3 and average of solid waste generated in MCO phase 4.

Overall, total waste collected by SWCorp in the eight states has shown reduction in total volume waste generated. This can be supported by articles from The Star where Director of Johor Solid Waste Management and Public Cleansing Corporation Sdn Bhd (SWCorp), Cairul Hisham Jalaluddin had told the press where the total volume of solid waste sent to landfill has decreased by 30% despite increased in volume of domestic waste in Johor due to people are subjected to stay at home order and practice the waste separation at source (Zazalia, 2020). Furthermore, the drop is ascribed to the government's directive to close business premises that provide non-essential services. In contrast, a survey study by Tan and Siti (2020) for Penang Green Council reported a reduction of total domestic waste since the early MCO implementation. Many people believed that solid waste generated by the household has increased during MCO which was in fact contradicting due to only a single source of waste that was contributed from the household due to people being mandated to stay at home rather than various sources.This is also had been proved by article from New Straits Time by Zazalia (2020) reported that a lack of contribution of solid waste from commercial, industrial and institutional from the closure non-essential business operations. To add, the rise in domestic garbage has not exceeded the increase in waste generated by commercial, industrial and institutional and some landfill operators have stated that the volume of waste entering their landfills has decreased by 10% to 30% per day in Malaysia since the MCO was adopted (Teoh, 2020).

Contradicting findings from the survey ACR+ (n.d.), the lockdown measures were not enough to offset the increase in domestic waste even though a large reduction of waste generated from economic activity was reported in most cities. To solve this problem, Naughton (2020) had explained in his study that the volume and type of refuse generated during this pandemic might have increased or decreased depending on the area. Moreover, the composition of MSW is heterogeneous within each community and influenced by income level, lifestyle, climate, household type, level of affluence, and region (Atanu, 2021). For example, the quantity of MSW generated in large and medium cities in Hubei Province, China, has decreased by 30%, while the output of medical waste has grown by more than 370% (Kleme et al. 2020; Atanu, 2021). The COVID-19 pandemic was also observed with highest plastic packaging waste produced from PPEs apart from food waste (Halter et al, 2020). In line with this, during the two-month circuit breaker period of stay-at-home curbs, an additional 1,334 tonnes of plastic garbage, equivalent to the weight of 92 double-decker buses, was generated from takeaway and delivery meals was reported in Singapore (Naveene, 2020).

5.3 The comparison of level of GHG emission (CO_2 CH_4) and leachate production by MSW generation before and during MCO in the study areas.

From the study, only the volume of domestic waste from the total volume of collected MSW data provided by SWCorp was used to calculate the methane and carbon dioxide emission in the landfilled. The IPCC methodology that comprises a theoretical gas yield-based equation was used to estimate the greenhouse gases (GHG) from the total solid waste generated in the eight states. This technique assumed that all potential methane was released in the year that solid waste was disposed of. The comparison of estimated GHG direct emission before and during MCO was shown statistically significant in all states. This is because of the reduction of total solid waste collected during MCO by SWCorp and less waste was sent to the landfill. Less waste that was sent to the landfill will lessen the global warming due to MSW is the major contributor to global warming from GHG emission (Rena et al., 2019). The United Nations Environment Programme (UNEP) recently released a report warning that the GHG emissions have increased at a rate of 1.4 percent per year on average since 2010 and that COVID-19 pandemic expects the 2020 emissions to fall by 7% from 2019 levels (The Jakarta Post, 2021).

There are different types of sources that constitute the GHG emission globally. According to the United States and Protection Agency (USEPA, n.d.), The primary and largest sources of GHG emission in the United States are burning fossil fuels from human activity. The fossil fuels will continue to rise if the primary source of energy used was fossil fuels. Malaysia's energy is derived from fossil fuels, primarily natural gas, coal, and petroleum (Amirreza et al., 2020). Despite that, from her study, during implementation of MCO in our country, there was a report of reduction in GHG emission, which was from 8 Mt CO2eq to <1 Mt CO2 eq during January to May 2020.

However, in terms of GHG emission from landfill gas, it is still worrying. This is because LFG consists of 50% methane, 50% carbon dioxide and non-methane organic compounds. Besides, methane is a powerful greenhouse gas that traps heat in the atmosphere 28 to 36 times more effectively than carbon dioxide over a 100-year period (IPCC, 2014). Malaysia depends on landfills as the primary source of waste disposal methods. According to Rangga et al. (2019), the states that adopted Act 672 generated 109,546.19 tonnes per year of methane and 2.74 million tonnes per year of carbon dioxide from landfilled domestic waste on average in 2019. The main contributor of GHG emission reported is landfill activity if compared with waste segregation and recycling (Liamsanguan & Gheewala, 2018). The landfilled Landfill gas has the ability to contribute to global warming, which will result in temperature changes and climate change (Ishigaki, 2011). There is strong evidence that these greenhouse gas emissions endanger human health both directly and indirectly, and that they will have long-term negative consequences for human development (Farooq et al., 2019). However, there is a study conducted in Indonesia that showed a reduction of GHG emission during pandemic COVID-19. According to the Suryawan et al. (2021), the entire global warming potential from waste output has been dramatically lowered from 1,859.6 kg CO2eq/day to 420.8 kg CO2eq/day from before and during pandemic.

This study also reported that there is a significant difference in leachate production before and during MCO in all states. As this estimation was based on the volume of waste disposed in landfill, the reduction of total waste collected during MCO has declined the volume of estimated leachate production in landfill. The total estimated leachate production during MCO was 507,996.13 m^3/yr. Nonetheless, there is no direct correlation between high solid waste dumped in landfill with volume of leachate production. This is because, the volume of leachate production in landfill will increase as it influenced by intensive precipitation (Aziz et al., 2012; Rangga et al., 2019). Furthermore, leachate is further influenced by landfill age, waste composition and moisture content (Maiti et al., 2016; Adhikari et al., 2014; Aziz et al., 2012; Rangga et al., 2019). According to Bernama (2020), the domestic sector accounts for 44.5 % of the 16,667.5 tonnes of food waste created daily in Malaysia stated by SWCorp Malaysia (Solid Waste and Public Cleansing Management Corporation). Despite the fact less waste was sent to the landfill during MCO, the high organic composition and moisture content constituted by food waste from domestic waste generated in Malaysia are prone to generate high leachate in landfill. In terms of environmental issues regarding leachate, Azmi (2018) reported that in 2017, leachate problems had recurred in six solid waste landfills in Malaysia. Leachate also posed a risk to human health from polluted drinking water sources with heavy metal. The most commonly found in landfill leachate include Chromium (Cr), Cadmium (Cd), Lead (Pb), Mercury (Hg), Nickel (Ni), Copper (Cu), Zinc (Zn), Iron (Fe) and Selenium (Urase *et al*., 1997). According to Khalil et al. (2018), serious cytotoxic and genotoxic effects were observed in the blood, bone marrow, and organs of mice, and the heavy metal compounds discovered in his study posed significant health and carcinogenic hazards.

5.4 The determination of health risk from NMVOC emissions before and during MCO in the study area.

The health risk estimated in this study was from the calculated inhalation exposure towards Non-Methane Volatile Organic Compound (NMVOC) emission in the landfill before and during MCO. There are four types of compounds that were assessed include Halogenated compound, oxygenated, sulphur, aromatic and alkane compounds. In this study, the emission from all compounds were reduced during MCO. The highest emission for halogenated compound was dichlorodifluoromethane (1.96E-02 - 3.76E-01 m^3/yr.). Meanwhile for oxygenated compound was 2-propanol (6.24E-02 - 1.20E+00 m^3/yr.). For sulphur compound was Hydrogen sulfide (4.42E-02 - 8.50E-01 m^3/yr.) and xylenes (1.51E-02 - 2.90E-01 m^3/yr) for aromatic compound. Lastly Propane was the highest emission for alkane compound with (1.38E-02 -2.66E-01 m^3/yr.)

The non-carcinogenic and carcinogenic health risks were assessed from selected NMVOC compounds in this study. The study showed an acceptable health risk for non-carcinogenic before and during MCO for all groups which are men, women and children as indicated by (HQ<1) in all states. Similar to non-carcinogenic health risk, health risk for carcinogenic compounds was an acceptable limit for before and during MCO for all groups which indicated by (LCR < 1.0E-4) in all states**.** This is because, this biogas is produced by the decomposition process of waste in the landfill usually produces less than 1% (Chalvatzaki & Lazaridis, 2010). A study by Carriero et al.

(2018) also reported acceptable health risk for NMVOC exposure. From his study by using GC–MS analysis found that, since the concentrations of VOC compounds simulated in nearby cities in the study area were below the threshold limits for acute and chronic diseases, the results suggested that fugitive emissions did not pose a severe threat to human health. Furthermore, highest concentration of NMVOC released was due to the solid waste was not being pre-treated prior to deposition in landfill (Pawłowska et al., 2008). However, estimation of NMVOC emitted in the landfill is essential despite the findings found in this study. This is due to that NMVOC emitted from a landfill can contain toxic and odorous gases that can cause health problems in the general public. Moreover, the exposure to aromatic VOCs including benzene, toluene, and 1–3 butadienes are potentially hazardous as high levels of exposure can affect human health (Na et al., 2003; Fang et al., 2019).

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study was carried out to determine the impacts of Movement Control Order (MCO) on Municipal Solid Waste (MSW) generation and the potential direct emission of landfill gas which is environmental pollutant and its potential health risk from landfilling activity in the states adopted Act 672. In conclusion, the characteristics (i.e. volume, waste composition) of solid waste generated from 2014 to 2020 were determined. The comparison between volume of waste generated before and during Movement Control Order (MCO) waste was determined. The level of GHG emission (methane and carbon dioxide), and health risk (non-carcinogenic and carcinogenic) was determined by using adopted mathematical equations. The level of GHG emission and health risk of the related solid waste generated before and during MCO were then compared by using statistical analysis. The result has shown that the volume of solid waste generated during MCO had declined from before MCO. However, only in quarter 2 (Q2) and MCO phase 2 the volume of solid waste generated has significantly difference between before and during MCO. As a conclusion, the occurrence of COVID 19 MCO provides the significant difference in volume solid waste generation before and during MCO that certainly affect the amount of GHG released and leachate production to the environment in the landfill and health risk.

6.2 Study Limitations and recommendations

In this study there were several inherent limitations that can be improved for future research. Firstly, the quantification of total collected domestic waste in this study was not accurately presented in this study as the fraction of waste composition was estimated from available data of solid waste collection from 2014 to 2018. Hence, the environmental and health effect analysis from landfilled domestic waste was affected in this study. Besides, the comparison of domestic waste generated before and during MCO and other type of composition such as plastic waste are essential as most of all the findings from the previous study has shown that during lockdown measures had significantly increased domestic waste and plastic waste globally. Other than that, the data was obtained with the limitation of assumption that only limited to states adopted Act 642 where it should be expand to other states and the data of solid waste collected should be available in daily.

Based on the findings from this study, there are several recommendations for the future research. Firstly, the study should expand to other states especially states with very high HDI to low HDI such as Selangor to see the trends of solid waste generation before and during MCO in Malaysia. Besides that, from the findings we can determine the effectiveness of solid waste management programmed implemented between the states. Although the volume of total solid waste generated during MCO has decreased in most of all study areas, however during the pandemic, the increased trend of household waste and the usage of single-use plastic is projected to rise to alarming. rates. Thus, segregation of waste at source and minimize waste generation by the household should be imposed with strict measures to accelerate these activities by Malaysian population. The disposed of plastic packaging from PPEs also should be adequately manage at source especially at the household level. The relevant authorities should develop a long-term and effective strategies for sustainable solid waste management in order to tackle solid waste generation issues, environmental pollution, public health, land use and socio-economic impacts. These strategic plans also essential to more effectively and efficiently control and reduce solid waste generation in Malaysia. Malaysian government also need to find suitable alternative for waste disposal method to practice in this country other than landfill. The easiest way is to convert waste-to-energy process and accelerate compositing and recycling activities. Last but not least, the most important thing is to increase the level of awareness among the public that the solid waste management is not only the responsibility by the government or the collector but it is a mutual responsibility at all level for a better Malaysia.

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APPENDIX B: TABLE OF RESULT

Appendix 1.1: The volume of municipal solid waste by composition in the study areas from 2014 to 2020.

Parameter	Year	States								Total	mean ±SD[b]
		WPKL	Putrajaya	Pahang	Perlis	Kedah	Negeri Sembilan	Melaka	Johor		
Domestic (tonne)	2014	680,806.63	26,193.53	302,233.41	49,440.65	309,494.57	218,617.04	360,734.76	810,829.75	2,758,350.33	344,793.79 ±277,248.18
	2015	613,561.50	28,649.16	308,009.50	63,792.00	433,996.39	233,137.48	313,950.85	818,515.73	2,813,612.60	351,701.58 ±266,700.70
	2016	614,357.93	29,360.29	247,664.08	41,269.00	424,287.45	245,802.71	214,688.00	912,033.82	2,729,463.28	341,182.91 ±299,625.37
	2017	610,849.75	28,903.84	242,309.86	30,366.10	345,456.08	242,538.16	218,275.08	839,252.11	2,557,950.98	319,743.87 ±279,252.23
	2018	610,068.90	29,360.29	229,811.12	30,118.21	388,397.00	252,529.82	203,308.89	869,692.81	2,613,287.04	326,660.88 ±289,193.79
	2019	629,285.90	42,026.85	228,696.68	35,603.01	413,214.66	200,146.20	246,032.15	760,098.71	2,555,104.15	319,388.02 ±26,3046.39
	2020	556,865.66	45,073.45	233,626.82	37,597.83	394,491.65	197,630.23	231,460.76	722,282.79	2,419,029.18	302,378.65 ±241,013.09
	Total	4,315,796.27	229,567.41	1,792,351.46	288,186.80	2,709,337.80	1,590,401.64	1788450.485	5732705.715	18,446,797.58	504,059.48

											±1,402,217.83
	mean ±SD[a]	616,542.32 ±36,381.25	32,795.34 ±7,477.64	256,050.21 ±34,232.77	41,169.54 ±11,991.57	677,334.45 ±44,865.12	397,600.41 ±22,128.86	255,492.93 ± 59,067.20	818,957.96 ±63,934.55	2,635,256.80 ±138,729.57	
Bulky and garden (tonne)	2014	210,279.28	22,619.60	48,119.79	6,391.39	48,867.92	29,215.74	55,800.69	111,624.43	532,918.84	66,614.86 ±65900.83
	2015	199,244.96	5,378.62	29,614.06	12,448.20	42,175.87	16,258.04	20,447.46	199,853.92	525,421.13	65,677.64 ±83369.94
	2016	170,412.73	4,085.69	36,940.12	10,596.00	43,793.04	18,920.77	12,968.49	110,317.27	408,034.11	51,004.26 ±58963.02
	2017	132,510.04	6,060.11	36,313.86	5,610.76	48,629.14	11,117.16	14,509.56	87,110.84	341,861.47	42,732.68 ±45707.71
	2018	126,122.18	8,034.53	39,180.92	5,913.13	59,104.74	10,564.95	43,055.89	32,011.77	323,988.11	40,498.51 ±39467.86
	2019	98,733.05	6,593.88	35,881.81	5,586.00	64,832.13	31,402.33	38,601.70	119,257.18	400,888.09	50,111.01 ±41271.18
	2020	87,370.53	7,071.89	36,655.34	5,898.98	61,894.54	31,007.58	36,315.49	113,323.98	379,538.34	47,442.29 ± 37814.22
	Total	1,024,672.77	59,844.32	262,705.90	52,444.47	369,297.38	148,486.58	221,699.28	773,499.39	2,912,650.09	364,081.26 ±360729.20
	mean ±SD[a]	146,381.82 ±47,976.55	8,549.19	37,529.41	7,492.07	52,756.77	21,212.37	31,671.33 ± 16,081.72	110,499.91 ±49,627.85	416,092.87 ±82,892.43	

			±6,330.06	±5,520.26	±2,816.99	±9,074.45	± 9,209.71				
Public cleansing (tonne)	2014	31,581.12	8,426.67	33,721.59	2,782.29	19,723.90	2,394.86	4,183.75	8,982.14	111,796.32	13,974.54 ±12,783.42
	2015	32,107.40	9,463.41	28,588.34	3,690.10	73,513.43	1,182.84	1,072.15	10,518.63	160,136.30	20,017.04 ±24,678.83
	2016	38,940.24	10,724.47	26,373.77	4,629.00	95,865.41	20,275.37	734.15	5,806.17	203,348.58	25,418.57 ±31,202.21
	2017	31,380.70	12,612.97	23,682.67	5,916.79	62,096.74	25,041.46	763.66	6,130.94	167,625.93	20,953.24 ±19,815.79
	2018	24,991.30	14,501.47	20,319.81	6,148.21	53,341.62	28,071.53	1,584.06	10,407.42	159,365.42	19,920.68 ±16,279.03
	2019	36,434.74	2,433.29	13,241.21	2,061.36	23,924.53	243,357.03	14,244.91	44,008.61	150,749.55	47,463.21 ±80556.67
	2020	32,241.72	2,609.69	13,526.65	2,176.86	22,840.50	11,442.50	13,401.24	41,819.13	142,721.21	17,507.29 ±13954.31
	Total	227,677.22	51,221.53	159,454.04	27,404.61	351,306.13	331,765.59	35,983.92	127,673.042	1,312,486.08	210,575.81 ±169,827.76
	mean ±SD[a]	32,525.32 ±4,390.39	7,317.36 ±7,029.37	22,779.15 ±7,636.00	3,914.94 ±1,697.79	50,186.59 ±29,291.59	47,395.08 ±87,046.76	5,140.56 ±6,052.79	18,239.01 ±16,970.09	187,498.01 ±87,508.85	

[a]mean ±SD by years for each of the state.
[b]mean ±SD by the states in each year

Appendix 1.2: The volume of municipal solid waste by regions in the study areas from 2014 to 2020.

Year	Type of regions			
	Northern Region	Central Region	South Region	East Region
2014	436,700.72	1,244,327.40	1,352,155.52	384,074.79
2015	629,615.99	1,134,898.62	1,364,358.74	366,211.90
2016	620,439.90	1,146,241.42	1,256,547.90	310,977.97
2017	498,075.61	1,094,461.33	1,166,042.19	302,306.39
2018	543,022.91	1,097,778.03	1,160,060.84	289,311.85
2019	545,715.77	1,059,603.74	1,223,350.83	278,071.45
2020	525,376.01	972,193.44	1,159,653.29	284,065.99
TOTAL	**3,798,946.91**	**7,749,503.98**	**8,682,169.30**	**2,215,020.34**
MIN	**436,700.72**	**972,193.44**	**1,159,653.29**	**278,071.45**
MAX	**629,615.99**	**1,244,327.40**	**1,364,358.74**	**384,074.79**
MEAN	**542,706.70**	**1,107,072.00**	**1,240,309.90**	**316,431.48**

Appendix 1.3: The solid waste generation before and during Movement Control Order (MCO) by states

Year	WPKL	Putrajaya	Pahang	Perlis	Kedah	Melaka	N. Sembilan	Johor	Total
Before MCO	765,146.42	51,100.29	278,071.45	43,289.57	502,426.20	299,149.59	243,357.03	924,201.24	3,106,741.78
During MCO	558,569.05	46,263.69	237,109.84	38,826.30	395,933.33	191,816.50	235,825.71	727,622.67	2,941,288.73
Total	1,323,715.47	97,363.98	515,181.29	82,115.87	898,359.53	490,966.09	479,182.74	1,651,823.91	6,048,030.51
Mean	661,857.73	48,681.99	257,590.65	41,057.94	449,179.76	245,483.05	239,591.37	825,911.95	3,024,015.26
SD	146,072.26	3,419.99	28,964.23	3,156.01	75,301.83	75,895.96	5,325.45	139,002.04	116,992.98

Appendix 1.4: The solid waste generation before and during Movement Control Order (MCO) by quarter

Appendix 1.5: The methane emission by solid waste generation before and during MCO by state

Year	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang	Total
Before	1,543.97	17,919.63	27,289.86	1,822.55	8,679.62	32,962.74	10,669.53	1,543.97	110,805.67
During	1,630.48	17,107.68	24,149.26	1,954.67	8,570.51	31,322.80	10,037.62	1,630.48	104,904.59
Total	1,587.23	17,513.66	25,719.56	1,888.61	8,625.07	32,142.77	10,353.57	10,024.65	215,710.26
Mean	61.17	574.14	2,220.74	93.42	77.15	1,159.61	446.83	151.18	107,855.13
SD	1,543.97	17,107.68	24,149.26	1,822.55	8,570.51	31,322.80	10,037.62	9,917.75	4,172.69
Min	1,630.48	17,919.63	27,289.86	1,954.67	8,679.62	32,962.74	10,669.53	10,131.55	104,904.59
Max	1,587.23	17,513.66	25,719.56	1,888.61	8,625.07	32,142.77	10,353.57	10,024.65	110,805.67

Appendix 1.6: The carbon dioxide emission by solid waste generation before and during MCO by state

Region/Year	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang	Total
Before	38,599.36	447,990.81	682,246.60	45,563.83	216,990.50	824,068.61	266,738.21	247,943.79	2,770,141.71
During	40,762.06	427,692.07	603,731.48	48,866.83	214,262.80	783,070.11	250,940.49	253,288.85	2,622,614.67
Total	79,361.42	875,682.88	1,285,978.07	94,430.66	431,253.30	1,607,138.72	517,678.71	501,232.64	5,392,756.39
Mean	39,680.71	437,841.44	642,989.04	47,215.33	215,626.65	803,569.36	258,839.35	250,616.32	2,696,378.19
SD	1,529.26	14,353.38	55,518.57	2,335.57	1,928.78	28,990.32	11,170.68	3,779.53	104,317.37

Appendix 1.7: The leachate production by food waste generation before and during MCO by states

Year	Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang	Total
Before	7,476.63	86,775.08	132,150.04	8,825.64	42,030.70	159,620.73	51,666.75	48,026.30	**536,571.87**
During	7,895.54	82,843.25	116,941.79	9,465.42	41,502.35	151,679.39	48,606.76	49,061.63	**507,996.13**
Total	15,372.18	169,618.33	249,091.83	18,291.06	83,533.05	311,300.11	100,273.51	97,087.93	1,044,568.00
Mean	7,686.09	84,809.16	124,545.91	9,145.53	41,766.53	155,650.06	50,136.75	48,543.97	522,284.00
SD	296.22	2,780.23	10,753.86	452.40	373.60	5,615.38	2,163.74	732.09	20,206.10

Appendix 1.8: Direct emission of Non-Methane Volatile Organic Compound (NMVOC) before MCO

Category	Parameter m3 year-1	Year 2019								
		State								
		Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang	Total before MCO
Halogenated compound	1,1,2,2-Tetrachloroethane	1.31E-03	1.52E-02	2.32E-02	1.55E-03	7.36E-03	2.80E-02	9.05E-03	8.42E-03	9.40E-02
	Methyl chloroform	5.67E-04	6.57E-03	1.00E-02	6.69E-04	3.18E-03	1.21E-02	3.91E-03	3.64E-03	4.07E-02
	Ethylidene dichloride	2.77E-03	3.22E-02	4.90E-02	3.27E-03	1.56E-02	5.92E-02	1.92E-02	1.78E-02	1.99E-01
	Vinylidene chloride	2.36E-04	2.74E-03	4.17E-03	2.79E-04	1.33E-03	5.04E-03	1.63E-03	1.52E-03	1.69E-02
	Ethylene dichloride	4.84E-04	5.62E-03	8.55E-03	5.71E-04	2.72E-03	1.03E-02	3.34E-03	3.11E-03	3.47E-02
	Propylene dichloride	2.12E-04	2.47E-03	3.75E-03	2.51E-04	1.19E-03	4.54E-03	1.47E-03	1.36E-03	1.52E-02
	Bromodichloromethane	3.69E-03	4.29E-02	6.53E-02	4.36E-03	2.08E-02	7.89E-02	2.55E-02	2.37E-02	2.65E-01
	Carbon tetrachloride	4.72E-06	5.48E-05	8.34E-05	5.57E-06	2.65E-05	1.01E-04	3.26E-05	3.03E-05	3.39E-04
	Chlorobenzene	2.95E-04	3.42E-03	5.22E-03	3.48E-04	1.66E-03	6.30E-03	2.04E-03	1.90E-03	2.12E-02
	Chlorodifluoromethane	1.53E-03	1.78E-02	2.71E-02	1.81E-03	8.63E-03	3.28E-02	1.06E-02	9.86E-03	1.10E-01
	Chloroethane	1.48E-03	1.71E-02	2.61E-02	1.74E-03	8.29E-03	3.15E-02	1.02E-02	9.48E-03	1.06E-01
	Chloroform	3.54E-05	4.11E-04	6.26E-04	4.18E-05	1.99E-04	7.56E-04	2.45E-04	2.27E-04	2.54E-03
	Chloromethane	1.43E-03	1.66E-02	2.52E-02	1.69E-03	8.03E-03	3.05E-02	9.87E-03	9.17E-03	1.02E-01
	Dichlorobenzene	2.48E-04	2.88E-03	4.38E-03	2.93E-04	1.39E-03	5.29E-03	1.71E-03	1.59E-03	1.78E-02
	Dichlorodifluoromethane	1.85E-02	2.15E-01	3.28E-01	2.19E-02	1.04E-01	3.96E-01	1.28E-01	1.19E-01	1.33E+00
	Dichlorofluoromethane	3.09E-03	3.59E-02	5.47E-02	3.65E-03	1.74E-02	6.60E-02	2.14E-02	1.99E-02	2.22E-01
	Dichloromethane	1.69E-02	1.96E-01	2.98E-01	1.99E-02	9.49E-02	3.60E-01	1.17E-01	1.08E-01	1.21E+00

	Ethylene dibromide	1.18E-06	1.37E-05	2.09E-05	1.39E-06	6.63E-06	2.52E-05	8.16E-06	7.58E-06	8.47E-05
	Trichloromethane	8.97E-04	1.04E-02	1.59E-02	1.06E-03	5.04E-03	1.91E-02	6.20E-03	5.76E-03	6.44E-02
	Tetrachloroethylene	4.40E-03	5.11E-02	7.78E-02	5.20E-03	2.47E-02	9.40E-02	3.04E-02	2.83E-02	3.16E-01
	t-1,2-dichloroethene	3.35E-03	3.89E-02	5.92E-02	3.96E-03	1.88E-02	7.16E-02	2.32E-02	2.15E-02	2.41E-01
	Trichloroethene	3.33E-03	3.86E-02	5.88E-02	3.93E-03	1.87E-02	7.11E-02	2.30E-02	2.14E-02	2.39E-01
	Vinyl chloride	8.66E-03	1.01E-01	1.53E-01	1.02E-02	4.87E-02	1.85E-01	5.99E-02	5.56E-02	6.22E-01
Oxygenated compound	2-Propanol	5.91E-02	6.86E-01	1.05E+00	6.98E-02	3.32E-01	1.26E+00	4.09E-01	3.80E-01	4.24E+00
	Acetone	8.27E-03	9.60E-02	1.46E-01	9.77E-03	4.65E-02	1.77E-01	5.72E-02	5.31E-02	5.94E-01
	Ethanol	3.21E-02	3.73E-01	5.67E-01	3.79E-02	1.80E-01	6.85E-01	2.22E-01	2.06E-01	2.30E+00
	Methyl ethyl ketone	8.37E-03	9.71E-02	1.48E-01	9.88E-03	4.70E-02	1.79E-01	5.78E-02	5.38E-02	6.01E-01
	Methyl isobutyl ketone	2.21E-03	2.56E-02	3.90E-02	2.61E-03	1.24E-02	4.71E-02	1.53E-02	1.42E-02	1.58E-01
Sulfur compound	Carbon disulfide	6.85E-04	7.94E-03	1.21E-02	8.08E-04	3.85E-03	1.46E-02	4.73E-03	4.40E-03	4.91E-02
	Carbonyl sulfide	5.78E-04	6.71E-03	1.02E-02	6.83E-04	3.25E-03	1.23E-02	4.00E-03	3.71E-03	4.15E-02
	Dimethyl sulfide	9.23E-03	1.07E-01	1.63E-01	1.09E-02	5.19E-02	1.97E-01	6.38E-02	5.93E-02	6.62E-01
	Ethyl mercaptan	2.69E-03	3.12E-02	4.76E-02	3.18E-03	1.51E-02	5.74E-02	1.86E-02	1.73E-02	1.93E-01
	Hydrogen sulfide	4.19E-02	4.86E-01	7.41E-01	4.95E-02	2.36E-01	8.94E-01	2.90E-01	2.69E-01	3.01E+00
	Methyl mercaptan	2.94E-03	3.41E-02	5.19E-02	3.47E-03	1.65E-02	6.27E-02	2.03E-02	1.89E-02	2.11E-01
Aromatic compound	Ethylbenzene	5.44E-03	6.31E-02	9.62E-02	6.42E-03	3.06E-02	1.16E-01	3.76E-02	3.49E-02	3.90E-01
	Xylenes	1.43E-02	1.66E-01	2.52E-01	1.69E-02	8.03E-02	3.05E-01	9.87E-02	9.17E-02	1.02E+00
Alkanes	Butane	5.94E-03	6.89E-02	1.05E-01	7.01E-03	3.34E-02	1.27E-01	4.10E-02	3.81E-02	4.26E-01
	Hexane	7.75E-03	9.00E-02	1.37E-01	9.15E-03	4.36E-02	1.66E-01	5.36E-02	4.98E-02	5.56E-01
	Pentane	3.88E-03	4.51E-02	6.86E-02	4.58E-03	2.18E-02	8.29E-02	2.68E-02	2.49E-02	2.79E-01
	Propane	1.31E-02	1.52E-01	2.32E-01	1.55E-02	7.36E-02	2.80E-01	9.05E-02	8.42E-02	9.40E-01

Appendix 1.9: Direct emission of Non-Methane Volatile Organic Compound (NMVOC) during MCO

Category	Parameter m3 year-1	Year 2020								
		State								
		Perlis	Kedah	Kuala Lumpur	Putrajaya	Negeri Sembilan	Johor	Malacca	Pahang	Total during MCO
Halogenated compound	1,1,2,2- Tetrachloroethane	1.38E-03	1.45E-02	2.05E-02	1.66E-03	7.27E-03	2.66E-02	8.52E-03	8.60E-03	8.90E-02
	Methyl chloroform	5.98E-04	6.28E-03	8.86E-03	7.17E-04	3.14E-03	1.15E-02	3.68E-03	3.72E-03	3.85E-02
	Ethylidene dichloride	2.93E-03	3.07E-02	4.34E-02	3.51E-03	1.54E-02	5.63E-02	1.80E-02	1.82E-02	1.88E-01
	Vinylidene chloride	2.49E-04	2.62E-03	3.69E-03	2.99E-04	1.31E-03	4.79E-03	1.53E-03	1.55E-03	1.60E-02
	Ethylene dichloride	5.11E-04	5.36E-03	7.57E-03	6.13E-04	2.69E-03	9.82E-03	3.15E-03	3.18E-03	3.29E-02
	Propylene dichloride	2.24E-04	2.35E-03	3.32E-03	2.69E-04	1.18E-03	4.31E-03	1.38E-03	1.39E-03	1.44E-02
	Bromodichloromethane	3.90E-03	4.09E-02	5.78E-02	4.68E-03	2.05E-02	7.49E-02	2.40E-02	2.42E-02	2.51E-01
	Carbon tetrachloride	4.99E-06	5.23E-05	7.38E-05	5.98E-06	2.62E-05	9.58E-05	3.07E-05	3.10E-05	3.21E-04
	Chlorobenzene	3.12E-04	3.27E-03	4.61E-03	3.74E-04	1.64E-03	5.99E-03	1.92E-03	1.94E-03	2.00E-02
	Chlorodifluoromethane	1.62E-03	1.70E-02	2.40E-02	1.94E-03	8.52E-03	3.11E-02	9.97E-03	1.01E-02	1.04E-01
	Chloroethane	1.56E-03	1.63E-02	2.31E-02	1.87E-03	8.19E-03	2.99E-02	9.59E-03	9.68E-03	1.00E-01
	Chloroform	3.74E-05	3.92E-04	5.54E-04	4.48E-05	1.97E-04	7.18E-04	2.30E-04	2.32E-04	2.41E-03
	Chloromethane	1.51E-03	1.58E-02	2.23E-02	1.81E-03	7.93E-03	2.90E-02	9.28E-03	9.37E-03	9.70E-02
	Dichlorobenzene	2.62E-04	2.75E-03	3.88E-03	3.14E-04	1.38E-03	5.03E-03	1.61E-03	1.63E-03	1.68E-02

	Dichlorodifluoromethane	1.96E-02	2.05E-01	2.90E-01	2.35E-02	1.03E-01	3.76E-01	1.20E-01	1.22E-01	1.26E+00
	Dichlorofluoromethane	3.27E-03	3.43E-02	4.84E-02	3.91E-03	1.72E-02	6.27E-02	2.01E-02	2.03E-02	2.10E-01
	Dichloromethane	1.78E-02	1.87E-01	2.64E-01	2.14E-02	9.37E-02	3.42E-01	1.10E-01	1.11E-01	1.15E+00
	Ethylene dibromide	1.25E-06	1.31E-05	1.85E-05	1.49E-06	6.55E-06	2.39E-05	7.67E-06	7.74E-06	8.02E-05
	Trichloromethane	9.47E-04	9.94E-03	1.40E-02	1.14E-03	4.98E-03	1.82E-02	5.83E-03	5.89E-03	6.09E-02
	Tetrachloroethylene	4.65E-03	4.88E-02	6.89E-02	5.57E-03	2.44E-02	8.93E-02	2.86E-02	2.89E-02	2.99E-01
	t-1,2-dichloroethene	3.54E-03	3.71E-02	5.24E-02	4.24E-03	1.86E-02	6.80E-02	2.18E-02	2.20E-02	2.28E-01
	Trichloroethene	3.51E-03	3.69E-02	5.21E-02	4.21E-03	1.85E-02	6.75E-02	2.16E-02	2.18E-02	2.26E-01
	Vinyl chloride	9.15E-03	9.60E-02	1.35E-01	1.10E-02	4.81E-02	1.76E-01	5.63E-02	5.68E-02	5.89E-01
Oxygenated compound	2-Propanol	6.24E-02	6.55E-01	9.25E-01	7.49E-02	3.28E-01	1.20E+00	3.84E-01	3.88E-01	4.02E+00
	Acetone	8.74E-03	9.17E-02	1.29E-01	1.05E-02	4.59E-02	1.68E-01	5.38E-02	5.43E-02	5.62E-01
	Ethanol	3.39E-02	3.56E-01	5.02E-01	4.06E-02	1.78E-01	6.51E-01	2.09E-01	2.11E-01	2.18E+00
	Methyl ethyl ketone	8.84E-03	9.27E-02	1.31E-01	1.06E-02	4.64E-02	1.70E-01	5.44E-02	5.49E-02	5.69E-01
	Methyl isobutyl ketone	2.33E-03	2.45E-02	3.45E-02	2.79E-03	1.23E-02	4.48E-02	1.43E-02	1.45E-02	1.50E-01
Sulfur compound	Carbon disulfide	7.23E-04	7.58E-03	1.07E-02	8.67E-04	3.80E-03	1.39E-02	4.45E-03	4.49E-03	4.65E-02
	Carbonyl sulfide	6.11E-04	6.41E-03	9.05E-03	7.32E-04	3.21E-03	1.17E-02	3.76E-03	3.79E-03	3.93E-02
	Dimethyl sulfide	9.75E-03	1.02E-01	1.44E-01	1.17E-02	5.12E-02	1.87E-01	6.00E-02	6.06E-02	6.27E-01
	Ethyl mercaptan	2.84E-03	2.98E-02	4.21E-02	3.41E-03	1.49E-02	5.46E-02	1.75E-02	1.77E-02	1.83E-01
	Hydrogen sulfide	4.42E-02	4.64E-01	6.55E-01	5.30E-02	2.33E-01	8.50E-01	2.72E-01	2.75E-01	2.85E+00
	Methyl mercaptan	3.10E-03	3.26E-02	4.60E-02	3.72E-03	1.63E-02	5.96E-02	1.91E-02	1.93E-02	2.00E-01
Aromatic	Ethylbenzene	5.75E-03	6.03E-02	8.51E-02	6.89E-03	3.02E-02	1.10E-01	3.54E-02	3.57E-02	3.70E-01

compound	Xylenes	1.51E-02	1.58E-01	2.23E-01	1.81E-02	7.93E-02	2.90E-01	9.28E-02	9.37E-02	9.70E-01
Alkanes	Butane	6.27E-03	6.58E-02	9.29E-02	7.52E-03	3.30E-02	1.20E-01	3.86E-02	3.90E-02	4.03E-01
	Hexane	8.19E-03	8.59E-02	1.21E-01	9.82E-03	4.30E-02	1.57E-01	5.04E-02	5.09E-02	5.27E-01
	Pentane	4.10E-03	4.30E-02	6.07E-02	4.92E-03	2.16E-02	7.88E-02	2.52E-02	2.55E-02	2.64E-01
	Propane	1.38E-02	1.45E-01	2.05E-01	1.66E-02	7.27E-02	2.66E-01	8.52E-02	8.60E-02	8.90E-01

Appendix 1.10: Non-carcinogenic health risk

State	Non-carcinogenic compound	Hazard quotient (HQ) Before MCO			Hazard quotient (HQ) During MCO		
		Man	Woman	Children	Man	Woman	Children
Perlis	Methyl chloroform	3.92E-11	4.07E-11	5.34E-11	4.13E-11	4.30E-11	5.64E-11
	Vinylidene chloride	4.08E-10	4.24E-10	5.57E-10	4.31E-10	4.48E-10	5.88E-10
	Propylene dichloride	1.84E-08	1.91E-08	2.51E-08	1.94E-08	2.02E-08	2.65E-08
	Carbon tetrachloride	1.63E-11	1.70E-11	2.23E-11	1.72E-11	1.79E-11	2.35E-11
	Chlorodifluoromethane	1.06E-11	1.10E-11	1.45E-11	1.12E-11	1.16E-11	1.53E-11
	Chloroethane	5.10E-11	5.30E-11	6.96E-11	5.38E-11	5.60E-11	7.35E-11
	Chloromethane	5.48E-09	5.70E-09	7.48E-09	5.79E-09	6.02E-09	7.90E-09
	Dichlorobenzene	1.07E-10	1.11E-10	1.46E-10	1.13E-10	1.18E-10	1.54E-10
	Dichloromethane	9.72E-09	1.01E-08	1.33E-08	1.03E-08	1.07E-08	1.40E-08
	Ethylene dibromide	4.53E-11	4.71E-11	6.19E-11	4.79E-11	4.98E-11	6.53E-11
	Tetrachloroethylene	3.80E-08	3.95E-08	5.19E-08	4.02E-08	4.18E-08	5.48E-08
	Trichloroethene	5.75E-07	5.98E-07	7.85E-07	6.07E-07	6.31E-07	8.29E-07
	Vinyl chloride	2.99E-08	3.11E-08	4.09E-08	3.16E-08	3.29E-08	4.32E-08

	Methyl ethyl ketone	5.78E-10	6.01E-10	7.89E-10	6.11E-10	6.35E-10	8.34E-10
	Methyl isobutyl ketone	2.54E-10	2.64E-10	3.47E-10	2.68E-10	2.79E-10	3.66E-10
	Carbon disulfide	3.38E-10	3.51E-10	4.61E-10	3.57E-10	3.71E-10	4.87E-10
	Xylene	4.93E-08	5.13E-08	6.74E-08	5.21E-08	5.42E-08	7.11E-08
	Hexane	3.83E-09	3.98E-09	5.23E-09	4.04E-09	4.20E-09	5.52E-09
	Pentane	1.34E-09	1.40E-09	1.83E-09	1.42E-09	1.47E-09	1.93E-09
Kedah	Methyl chloroform	1.67E-10	1.74E-10	2.28E-10	4.34E-10	4.51E-10	5.92E-10
	Vinylidene chloride	1.74E-09	1.81E-09	2.38E-09	4.52E-09	4.70E-09	6.17E-09
	Propylene dichloride	7.83E-08	8.15E-08	1.07E-07	2.03E-07	2.11E-07	2.78E-07
	Carbon tetrachloride	6.96E-11	7.24E-11	9.51E-11	1.81E-10	1.88E-10	2.47E-10
	Chlorodifluoromethane	4.53E-11	4.71E-11	6.18E-11	1.17E-10	1.22E-10	1.60E-10
	Chloroethane	2.18E-10	2.26E-10	2.97E-10	5.65E-10	5.87E-10	7.71E-10
	Chloromethane	2.34E-08	2.43E-08	3.20E-08	6.08E-08	6.32E-08	8.29E-08
	Dichlorobenzene	4.57E-10	4.75E-10	6.24E-10	1.19E-09	1.23E-09	1.62E-09
	Dichloromethane	4.15E-08	4.31E-08	5.66E-08	1.08E-07	1.12E-07	1.47E-07
	Ethylene dibromide	1.93E-10	2.01E-10	2.64E-10	5.02E-10	5.22E-10	6.85E-10
	Tetrachloroethylene	1.62E-07	1.69E-07	2.22E-07	4.21E-07	4.38E-07	5.75E-07

	Trichloroethene	2.45E-06	2.55E-06	3.35E-06	6.37E-06	6.63E-06	8.70E-06
	Vinyl chloride	1.28E-07	1.33E-07	1.74E-07	3.32E-07	3.45E-07	4.53E-07
	Methyl ethyl ketone	2.47E-09	2.57E-09	3.37E-09	6.41E-09	6.66E-09	8.75E-09
	Methyl isobutyl ketone	1.09E-09	1.13E-09	1.48E-09	2.82E-09	2.93E-09	3.85E-09
	Carbon disulfide	1.44E-09	1.50E-09	1.97E-09	3.74E-09	3.89E-09	5.11E-09
	Xylene	2.11E-07	2.19E-07	2.88E-07	5.47E-07	5.69E-07	7.46E-07
	Hexane	1.63E-08	1.70E-08	2.23E-08	4.24E-08	4.41E-08	5.79E-08
	Pentane	5.73E-09	5.96E-09	7.82E-09	1.49E-08	1.55E-08	2.03E-08
Kuala Lumpur	Methyl chloroform	6.92E-10	7.20E-10	9.45E-10	6.12E-10	6.37E-10	8.36E-10
	Vinylidene chloride	7.21E-09	7.50E-09	9.84E-09	6.38E-09	6.63E-09	8.71E-09
	Propylene dichloride	3.24E-07	3.37E-07	4.43E-07	2.87E-07	2.99E-07	3.92E-07
	Carbon tetrachloride	2.88E-10	3.00E-10	3.94E-10	2.55E-10	2.65E-10	3.48E-10
	Chlorodifluoromethane	1.87E-10	1.95E-10	2.56E-10	1.66E-10	1.72E-10	2.26E-10
	Chloroethane	9.01E-10	9.37E-10	1.23E-09	7.97E-10	8.29E-10	1.09E-09
	Chloromethane	9.69E-08	1.01E-07	1.32E-07	8.58E-08	8.92E-08	1.17E-07
	Dichlorobenzene	1.89E-09	1.97E-09	2.58E-09	1.67E-09	1.74E-09	2.29E-09
	Dichloromethane	1.72E-07	1.79E-07	2.35E-07	1.52E-07	1.58E-07	2.08E-07

	Ethylene dibromide	8.01E-10	8.33E-10	1.09E-09	7.09E-10	7.37E-10	9.67E-10
	Tetrachloroethylene	6.72E-07	6.99E-07	9.18E-07	5.95E-07	6.19E-07	8.12E-07
	Trichloroethene	1.02E-05	1.06E-05	1.39E-05	8.99E-06	9.35E-06	1.23E-05
	Vinyl chloride	5.29E-07	5.50E-07	7.22E-07	4.68E-07	4.87E-07	6.39E-07
	Methyl ethyl ketone	1.02E-08	1.06E-08	1.40E-08	9.05E-09	9.41E-09	1.23E-08
	Methyl isobutyl ketone	4.49E-09	4.67E-09	6.13E-09	3.98E-09	4.13E-09	5.43E-09
	Carbon disulfide	5.97E-09	6.21E-09	8.15E-09	5.29E-09	5.50E-09	7.21E-09
	Xylene	8.72E-07	9.07E-07	1.19E-06	7.72E-07	8.03E-07	1.05E-06
	Hexane	6.77E-08	7.04E-08	9.24E-08	5.99E-08	6.23E-08	8.17E-08
	Pentane	2.37E-08	2.47E-08	3.24E-08	2.10E-08	2.18E-08	2.86E-08
Putrajaya	Methyl chloroform	1.70E-11	1.77E-11	2.32E-11	4.96E-11	5.15E-11	6.77E-11
	Vinylidene chloride	1.77E-10	1.84E-10	2.42E-10	5.16E-10	5.37E-10	7.05E-10
	Propylene dichloride	7.97E-09	8.29E-09	1.09E-08	2.32E-08	2.42E-08	3.17E-08
	Carbon tetrachloride	7.08E-12	7.37E-12	9.67E-12	2.07E-11	2.15E-11	2.82E-11
	Chlorodifluoromethane	4.60E-12	4.79E-12	6.28E-12	1.34E-11	1.40E-11	1.83E-11
	Chloroethane	2.21E-11	2.30E-11	3.02E-11	6.45E-11	6.71E-11	8.81E-11
	Chloromethane	2.38E-09	2.48E-09	3.25E-09	6.94E-09	7.22E-09	9.48E-09

	Dichlorobenzene	4.65E-11	4.83E-11	6.34E-11	1.36E-10	1.41E-10	1.85E-10
	Dichloromethane	4.22E-09	4.39E-09	5.76E-09	1.23E-08	1.28E-08	1.68E-08
	Ethylene dibromide	1.97E-11	2.05E-11	2.69E-11	5.74E-11	5.97E-11	7.83E-11
	Tetrachloroethylene	1.65E-08	1.72E-08	2.25E-08	4.81E-08	5.01E-08	6.57E-08
	Trichloroethene	2.50E-07	2.60E-07	3.41E-07	7.28E-07	7.57E-07	9.94E-07
	Vinyl chloride	1.30E-08	1.35E-08	1.77E-08	3.79E-08	3.94E-08	5.17E-08
	Methyl ethyl ketone	2.51E-10	2.61E-10	3.43E-10	7.32E-10	7.61E-10	9.99E-10
	Methyl isobutyl ketone	1.10E-10	1.15E-10	1.51E-10	3.22E-10	3.35E-10	4.39E-10
	Carbon disulfide	1.47E-10	1.52E-10	2.00E-10	4.28E-10	4.45E-10	5.84E-10
	Xylene	2.14E-08	2.23E-08	2.92E-08	6.25E-08	6.50E-08	8.53E-08
	Hexane	1.66E-09	1.73E-09	2.27E-09	4.85E-09	5.04E-09	6.61E-09
	Pentane	5.83E-10	6.06E-10	7.95E-10	1.70E-09	1.77E-09	2.32E-09
Negeri Sembilan	Methyl chloroform	8.10E-11	8.42E-11	1.11E-10	2.17E-10	2.26E-10	2.97E-10
	Vinylidene chloride	8.43E-10	8.77E-10	1.15E-09	2.26E-09	2.35E-09	3.09E-09
	Propylene dichloride	3.79E-08	3.95E-08	5.18E-08	1.02E-07	1.06E-07	1.39E-07
	Carbon tetrachloride	3.37E-11	3.51E-11	4.60E-11	9.06E-11	9.42E-11	1.24E-10
	Chlorodifluoromethane	2.19E-11	2.28E-11	2.99E-11	5.89E-11	6.12E-11	8.03E-11

	Chloroethane	1.05E-10	1.10E-10	1.44E-10	2.83E-10	2.94E-10	3.86E-10
	Chloromethane	1.13E-08	1.18E-08	1.55E-08	3.04E-08	3.17E-08	4.15E-08
	Dichlorobenzene	2.21E-10	2.30E-10	3.02E-10	5.94E-10	6.18E-10	8.11E-10
	Dichloromethane	2.01E-08	2.09E-08	2.74E-08	5.40E-08	5.61E-08	7.37E-08
	Ethylene dibromide	9.37E-11	9.74E-11	1.28E-10	2.52E-10	2.62E-10	3.43E-10
	Tetrachloroethylene	7.86E-08	8.18E-08	1.07E-07	2.11E-07	2.20E-07	2.88E-07
	Trichloroethene	1.19E-06	1.24E-06	1.62E-06	3.19E-06	3.32E-06	4.36E-06
	Vinyl chloride	6.19E-08	6.44E-08	8.45E-08	1.66E-07	1.73E-07	2.27E-07
	Methyl ethyl ketone	1.20E-09	1.24E-09	1.63E-09	3.21E-09	3.34E-09	4.38E-09
	Methyl isobutyl ketone	5.26E-10	5.47E-10	7.18E-10	1.41E-09	1.47E-09	1.93E-09
	Carbon disulfide	7.01E-10	7.29E-10	9.57E-10	1.88E-09	1.95E-09	2.56E-09
	Xylene	1.02E-07	1.06E-07	1.39E-07	2.74E-07	2.85E-07	3.74E-07
	Hexane	7.91E-09	8.23E-09	1.08E-08	2.12E-08	2.21E-08	2.90E-08
	Pentane	2.77E-09	2.89E-09	3.79E-09	7.45E-09	7.75E-09	1.02E-08
Johor	Methyl chloroform	8.36E-10	8.69E-10	1.14E-09	7.94E-10	8.26E-10	1.08E-09
	Vinylidene chloride	8.71E-09	9.05E-09	1.19E-08	8.27E-09	8.60E-09	1.13E-08
	Propylene dichloride	3.92E-07	4.07E-07	5.35E-07	3.72E-07	3.87E-07	5.08E-07

	Carbon tetrachloride	3.48E-10	3.62E-10	4.75E-10	3.31E-10	3.44E-10	4.52E-10
	Chlorodifluoromethane	2.26E-10	2.35E-10	3.09E-10	2.15E-10	2.24E-10	2.94E-10
	Chloroethane	1.09E-09	1.13E-09	1.49E-09	1.03E-09	1.08E-09	1.41E-09
	Chloromethane	1.17E-07	1.22E-07	1.60E-07	1.11E-07	1.16E-07	1.52E-07
	Dichlorobenzene	2.29E-09	2.38E-09	3.12E-09	2.17E-09	2.26E-09	2.96E-09
	Dichloromethane	2.08E-07	2.16E-07	2.83E-07	1.97E-07	2.05E-07	2.69E-07
	Ethylene dibromide	9.67E-10	1.01E-09	1.32E-09	9.19E-10	9.56E-10	1.25E-09
	Tetrachloroethylene	8.12E-07	8.44E-07	1.11E-06	7.72E-07	8.02E-07	1.05E-06
	Trichloroethene	1.23E-05	1.28E-05	1.68E-05	1.17E-05	1.21E-05	1.59E-05
	Vinyl chloride	6.39E-07	6.65E-07	8.72E-07	6.07E-07	6.32E-07	8.29E-07
	Methyl ethyl ketone	1.23E-08	1.28E-08	1.69E-08	1.17E-08	1.22E-08	1.60E-08
	Methyl isobutyl ketone	5.43E-09	5.64E-09	7.41E-09	5.16E-09	5.36E-09	7.04E-09
	Carbon disulfide	7.21E-09	7.50E-09	9.85E-09	6.86E-09	7.13E-09	9.36E-09
	Xylene	1.05E-06	1.10E-06	1.44E-06	1.00E-06	1.04E-06	1.37E-06
	Hexane	8.17E-08	8.50E-08	1.12E-07	7.77E-08	8.08E-08	1.06E-07
	Pentane	2.86E-08	2.98E-08	3.91E-08	2.72E-08	2.83E-08	3.72E-08
Malacca	Methyl chloroform	9.95E-11	1.03E-10	1.36E-10	2.55E-10	2.65E-10	3.47E-10

	Vinylidene chloride	1.04E-09	1.08E-09	1.41E-09	2.65E-09	2.76E-09	3.62E-09
	Propylene dichloride	4.66E-08	4.85E-08	6.37E-08	1.19E-07	1.24E-07	1.63E-07
	Carbon tetrachloride	4.15E-11	4.31E-11	5.66E-11	1.06E-10	1.10E-10	1.45E-10
	Chlorodifluoromethane	2.70E-11	2.80E-11	3.68E-11	6.89E-11	7.17E-11	9.41E-11
	Chloroethane	1.30E-10	1.35E-10	1.77E-10	3.31E-10	3.45E-10	4.52E-10
	Chloromethane	1.39E-08	1.45E-08	1.90E-08	3.56E-08	3.71E-08	4.87E-08
	Dichlorobenzene	2.72E-10	2.83E-10	3.71E-10	6.96E-10	7.24E-10	9.50E-10
	Dichloromethane	2.47E-08	2.57E-08	3.37E-08	6.32E-08	6.57E-08	8.63E-08
	Ethylene dibromide	1.15E-10	1.20E-10	1.57E-10	2.95E-10	3.06E-10	4.02E-10
	Tetrachloroethylene	9.67E-08	1.01E-07	1.32E-07	2.47E-07	2.57E-07	3.37E-07
	Trichloroethene	1.46E-06	1.52E-06	2.00E-06	3.74E-06	3.89E-06	5.10E-06
	Vinyl chloride	7.61E-08	7.91E-08	1.04E-07	1.95E-07	2.02E-07	2.66E-07
	Methyl ethyl ketone	1.47E-09	1.53E-09	2.01E-09	3.76E-09	3.91E-09	5.13E-09
	Methyl isobutyl ketone	6.46E-10	6.72E-10	8.82E-10	1.65E-09	1.72E-09	2.26E-09
	Carbon disulfide	8.59E-10	8.93E-10	1.17E-09	2.20E-09	2.28E-09	3.00E-09
	Xylene	1.35E-07	1.40E-07	1.84E-07	3.21E-07	3.34E-07	4.38E-07
	Hexane	9.73E-09	1.01E-08	1.33E-08	2.49E-08	2.59E-08	3.40E-08

	Pentane	3.41E-09	3.55E-09	4.66E-09	8.72E-09	9.07E-09	1.19E-08
Pahang	Methyl chloroform	2.51E-10	2.62E-10	3.43E-10	2.57E-10	2.67E-10	3.51E-10
	Vinylidene chloride	2.62E-09	2.72E-09	3.58E-09	2.68E-09	2.78E-09	3.65E-09
	Propylene dichloride	1.18E-07	1.23E-07	1.61E-07	1.20E-07	1.25E-07	1.64E-07
	Carbon tetrachloride	1.05E-10	1.09E-10	1.43E-10	1.07E-10	1.11E-10	1.46E-10
	Chlorodifluoromethane	6.81E-11	7.08E-11	9.30E-11	6.96E-11	7.24E-11	9.50E-11
	Chloroethane	3.27E-10	3.41E-10	4.47E-10	3.35E-10	3.48E-10	4.57E-10
	Chloromethane	3.52E-08	3.66E-08	4.81E-08	3.60E-08	3.74E-08	4.91E-08
	Dichlorobenzene	6.88E-10	7.15E-10	9.39E-10	7.02E-10	7.31E-10	9.59E-10
	Dichloromethane	6.24E-08	6.49E-08	8.52E-08	6.38E-08	6.63E-08	8.71E-08
	Ethylene dibromide	2.91E-10	3.03E-10	3.97E-10	2.97E-10	3.09E-10	4.06E-10
	Tetrachloroethylene	2.44E-07	2.54E-07	3.33E-07	2.50E-07	2.60E-07	3.41E-07
	Trichloroethene	3.69E-06	3.84E-06	5.04E-06	3.77E-06	3.92E-06	5.15E-06
	Vinyl chloride	1.92E-07	2.00E-07	2.62E-07	1.96E-07	2.04E-07	2.68E-07
	Methyl ethyl ketone	3.71E-09	3.86E-09	5.07E-09	3.79E-09	3.95E-09	5.18E-09
	Methyl isobutyl ketone	1.63E-09	1.70E-09	2.23E-09	1.67E-09	1.73E-09	2.28E-09
	Carbon disulfide	2.17E-09	2.26E-09	2.96E-09	2.22E-09	2.31E-09	3.03E-09

	Xylene	3.17E-07	3.30E-07	4.33E-07	3.24E-07	3.37E-07	4.42E-07
	Hexane	2.46E-08	2.56E-08	3.36E-08	2.51E-08	2.61E-08	3.43E-08
	Pentane	8.62E-09	8.96E-09	1.18E-08	8.80E-09	9.16E-09	1.20E-08

[a]Note: Potential health risks through inhalation exposure were estimated for different inhalation rate (15m^3/day-child; 23m^3/day-Adult man; 21m^3/day-Adult woman (WHO, 1994; WHO, 1999)), lifetime expectancy (Female: 77.6 and Male: 72.7 (DOSM, 2018)), and average body weight (Child: 31.8 kg (U.S EPA, 2009); Adult man: 66.56kg; and Adult woman 58.44 (Azmi et al., 2009))

Appendix 1.10: Carcinogenic health risk

State	Carcinogenic compound	Life time cancer risk (LCR) before MCO			Life time cancer risk (LCR) during MCO		
		Man	Woman	Children	Man	Woman	Children
Perlis	Ethylene dichloride	1.20E-18	1.17E-18	1.19E-17	1.26E-18	1.23E-18	1.25E-17
	Carbon tetrachloride	2.69E-21	2.63E-21	2.67E-20	2.84E-21	2.77E-21	2.82E-20
	Chloroform	7.74E-20	7.55E-20	7.68E-19	8.18E-20	7.97E-20	8.11E-19
	Dichloromethane	1.60E-20	1.56E-20	1.59E-19	1.69E-20	1.65E-20	1.68E-19
	Ethylene dibromide	6.73E-20	6.56E-20	6.68E-19	7.11E-20	6.93E-20	7.05E-19
	Tetrachloroethylene	1.09E-19	1.06E-19	1.08E-18	1.15E-19	1.12E-19	1.14E-18
	Trichloroethene	1.30E-18	1.26E-18	1.29E-17	1.37E-18	1.34E-18	1.36E-17
	Vinyl chloride	7.25E-18	7.07E-18	7.19E-17	7.65E-18	7.46E-18	7.59E-17
Kedah	Ethylene dichloride	1.39E-17	1.35E-17	1.38E-16	1.39E-17	1.35E-17	1.38E-16
	Carbon tetrachloride	3.13E-20	3.05E-20	3.10E-19	3.13E-20	3.05E-20	3.10E-19
	Chloroform	8.98E-19	8.76E-19	8.92E-18	8.98E-19	8.76E-19	8.92E-18
	Dichloromethane	1.86E-19	1.82E-19	1.85E-18	1.86E-19	1.82E-19	1.85E-18
	Ethylene dibromide	7.81E-19	7.62E-19	7.75E-18	7.81E-19	7.62E-19	7.75E-18
	Tetrachloroethylene	1.26E-18	1.23E-18	1.25E-17	1.26E-18	1.23E-18	1.25E-17
	Trichloroethene	1.51E-17	1.47E-17	1.49E-16	1.51E-17	1.47E-17	1.49E-16
	Vinyl chloride	8.41E-17	8.20E-17	8.35E-16	8.41E-17	8.20E-17	8.35E-16
Kuala Lumpur	Ethylene dichloride	2.11E-17	2.06E-17	2.10E-16	1.87E-17	1.82E-17	1.86E-16
	Carbon tetrachloride	4.76E-20	4.64E-20	4.72E-19	4.21E-20	4.11E-20	4.18E-19
	Chloroform	1.37E-18	1.33E-18	1.36E-17	1.21E-18	1.18E-18	1.20E-17
	Dichloromethane	2.84E-19	2.76E-19	2.81E-18	2.51E-19	2.45E-19	2.49E-18
	Ethylene dibromide	1.19E-18	1.16E-18	1.18E-17	1.05E-18	1.03E-18	1.04E-17
	Tetrachloroethylene	1.92E-18	1.87E-18	1.91E-17	1.70E-18	1.66E-18	1.69E-17
	Trichloroethene	2.29E-17	2.24E-17	2.28E-16	2.03E-17	1.98E-17	2.01E-16

	Vinyl chloride	1.28E-16	1.25E-16	1.27E-15	1.13E-16	1.11E-16	1.12E-15
Putrajaya	Ethylene dichloride	1.41E-18	1.38E-18	1.40E-17	1.51E-18	1.48E-18	1.50E-17
	Carbon tetrachloride	3.18E-21	3.10E-21	3.15E-20	3.41E-21	3.32E-21	3.38E-20
	Chloroform	9.14E-20	8.91E-20	9.07E-19	9.80E-20	9.55E-20	9.73E-19
	Dichloromethane	1.89E-20	1.85E-20	1.88E-19	2.03E-20	1.98E-20	2.02E-19
	Ethylene dibromide	7.95E-20	7.75E-20	7.89E-19	8.52E-20	8.31E-20	8.46E-19
	Tetrachloroethylene	1.28E-19	1.25E-19	1.27E-18	1.38E-19	1.34E-19	1.37E-18
	Trichloroethene	1.53E-18	1.49E-18	1.52E-17	1.64E-18	1.60E-18	1.63E-17
	Vinyl chloride	8.55E-18	8.34E-18	8.49E-17	9.17E-18	8.94E-18	9.10E-17
Negeri Sembilan	Ethylene dichloride	6.72E-18	6.55E-18	6.67E-17	6.64E-18	6.47E-18	6.59E-17
	Carbon tetrachloride	1.51E-20	1.48E-20	1.50E-19	1.49E-20	1.46E-20	1.48E-19
	Chloroform	4.35E-19	4.24E-19	4.32E-18	4.30E-19	4.19E-19	4.26E-18
	Dichloromethane	9.02E-20	8.79E-20	8.95E-19	8.91E-20	8.68E-20	8.84E-19
	Ethylene dibromide	3.78E-19	3.69E-19	3.76E-18	3.74E-19	3.64E-19	3.71E-18
	Tetrachloroethylene	6.12E-19	5.96E-19	6.07E-18	6.04E-19	5.89E-19	5.99E-18
	Trichloroethene	7.29E-18	7.11E-18	7.24E-17	7.20E-18	7.02E-18	7.15E-17
	Vinyl chloride	4.07E-17	3.97E-17	4.04E-16	4.02E-17	3.92E-17	3.99E-16
Johor	Ethylene dichloride	2.55E-17	2.49E-17	2.53E-16	2.43E-17	2.37E-17	2.41E-16
	Carbon tetrachloride	5.75E-20	5.60E-20	5.70E-19	5.46E-20	5.33E-20	5.42E-19
	Chloroform	1.65E-18	1.61E-18	1.64E-17	1.57E-18	1.53E-18	1.56E-17
	Dichloromethane	3.43E-19	3.34E-19	3.40E-18	3.25E-19	3.17E-19	3.23E-18
	Ethylene dibromide	1.44E-18	1.40E-18	1.43E-17	1.37E-18	1.33E-18	1.36E-17
	Tetrachloroethylene	2.32E-18	2.26E-18	2.31E-17	2.21E-18	2.15E-18	2.19E-17
	Trichloroethene	2.77E-17	2.70E-17	2.75E-16	2.63E-17	2.57E-17	2.61E-16
	Vinyl chloride	1.55E-16	1.51E-16	1.54E-15	1.47E-16	1.43E-16	1.46E-15
Malacca	Ethylene dichloride	8.26E-18	8.06E-18	8.20E-17	7.78E-18	7.58E-18	7.72E-17
	Carbon tetrachloride	1.86E-20	1.81E-20	1.85E-19	1.75E-20	1.71E-20	1.74E-19
	Chloroform	5.35E-19	5.22E-19	5.31E-18	5.03E-19	4.91E-19	4.99E-18

	Dichloromethane	1.11E-19	1.08E-19	1.10E-18	1.04E-19	1.02E-19	1.04E-18
	Ethylene dibromide	4.65E-19	4.54E-19	4.62E-18	4.38E-19	4.27E-19	4.34E-18
	Tetrachloroethylene	7.52E-19	7.33E-19	7.46E-18	7.07E-19	6.90E-19	7.02E-18
	Trichloroethene	8.96E-18	8.74E-18	8.90E-17	8.43E-18	8.22E-18	8.37E-17
	Vinyl chloride	5.01E-17	4.88E-17	4.97E-16	4.71E-17	4.59E-17	4.68E-16
Pahang	Ethylene dichloride	7.68E-18	7.49E-18	7.62E-17	7.85E-18	7.65E-18	7.79E-17
	Carbon tetrachloride	1.73E-20	1.69E-20	1.72E-19	1.77E-20	1.72E-20	1.75E-19
	Chloroform	4.97E-19	4.85E-19	4.93E-18	5.08E-19	4.95E-19	5.04E-18
	Dichloromethane	1.03E-19	1.00E-19	1.02E-18	1.05E-19	1.03E-19	1.04E-18
	Ethylene dibromide	4.32E-19	4.22E-19	4.29E-18	4.42E-19	4.31E-19	4.38E-18
	Tetrachloroethylene	6.99E-19	6.81E-19	6.94E-18	7.14E-19	6.96E-19	7.09E-18
	Trichloroethene	8.33E-18	8.12E-18	8.27E-17	8.51E-18	8.30E-18	8.45E-17
	Vinyl chloride	4.66E-17	4.54E-17	4.62E-16	4.76E-17	4.64E-17	4.72E-16

[a]Note: Potential health risks through inhalation exposure were estimated for different inhalation rate ($15m^3$/day-child; $23m^3$/day-Adult man; $21m^3$/day-Adult woman (WHO, 1994; WHO, 1999)), lifetime expectancy (Female: 77.6 and Male: 72.7 (DOSM, 2018)), and average body weight (Child: 31.8 kg (U.S EPA, 2009); Adult man: 66.56kg; and Adult woman 58.44 (Azmi et al., 2009