MODELLING AIR POLLUTION AND EMERGENCY DEPARTMENT VISITS AMONG CHILDREN WITH RESPIRATORY DISEASES IN RELATION TO PHASES OF THE MOVEMENT CONTROL ORDER (MCO) IN MALAYSIA

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by

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DECLARATION

I declare that the thesis has been composed by myself in the manuscript-based thesis writing as an alternative format approved by the School of Medical Sciences, Universiti Sains Malaysia, and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work which has formed part of jointly authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated in the list of manuscripts. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

Dr Afiqah Syamimi binti Masrani

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LIST OF MANUSCRIPTS

During my Doctor of Public Health (DrPH) course, four manuscripts were successfully prepared. The first manuscript was written as part of the literature review whereas the second to fourth manuscripts corresponded with the study's objectives. Two manuscripts have been published and presented at international conferences, whilst another two are awaiting submission to a World of Science indexed journal.

First manuscript
(As part of the literature review)

Five decades of research progress in air pollution, children's respiratory health, and emergency department visits: a bibliometric analysis

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Published in the Cureus Journal of Medical Science 15(4): e37151
(doi: 10.7759/cureus.37151)

Presented at the 3rd World Conference on Public Health 2022
(9 – 10 December 2022)
(Overall Best Presentation Award)

Second manuscript
(Corresponding to the first research objective)

The changing trend of paediatric emergency department visits in Malaysia following the COVID-19 pandemic

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Third manuscript
(Corresponding to the second and third research objectives)

The impact of the COVID-19 pandemic lockdown on air pollution and paediatric emergency department visits for respiratory disease in Malaysia

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Final draft prepared for submission

Fourth manuscript
(Corresponding to the third and fourth research objectives)

Modelling the relationship between air pollution and respiratory-related emergency department visits among children across the pre, during, and post-lockdown periods in Malaysia

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Final draft prepared for submission

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LIST OF SYMBOLS

%	Percentage
>	More than
<	Less than
ºC	Degree Celsius
β0	Intercept value
β1	Slope value
µg	Microgram
µm	Micrometre
d	Cohen's d for effect size
k	Knots
km^2	Kilometre square
m^3	Cubic meter
mg	Milligram
mm	Millimetres
m/s	Meter per second
n	Number
p	P-value
R^2	Coefficient of determinant in regression analysis
r	Correlation coefficient
s	Smoothing parameter
t	Welch T-test statistic
x	Event or variable under investigation

LIST OF ABBREVIATIONS

AIC	Aikake Information Criterion
ANOVA	Analysis of variance
API	Air Pollution Index
APN	Asia-Pacific Network for Global Change Research
ARIMA	Auto-Regressive Integrated Moving Average model
BC	Before Christ (in historical terms)
BIC	Bayesian Information Criterion
bs	Basis spline
CAQMS	Continuous Air Quality Monitoring Station
cc	Cyclic cubic regression spline
CI	Confidence interval
CO	Carbon monoxide
COVID-19	Coronavirus disease 2019
df	Degrees of freedom
DLNM	Distributed lag non-linear model
DOE	Department of Environment Malaysia
ED	Emergency department
edf	Effective degrees of freedom
ERR	Excess relative risks
FEV1	Forced expiratory volume in the first-second
FVC	Forced vital capacity
GAM	Generalized additive model
GOME	Global Ozone Monitoring Experiment
H-indexed	A metric for evaluating the cumulative impact of an author's scholarly output and performance
HEPA	high-efficiency particulate absorbing filter and high-efficiency particulate are stance filter
SD	Standard deviation
SE	Standard error
IARC	International Agency for Research on Cancer
ICD-10-CM	10th revision of the International Classification of Diseases Clinical Modification
ICU	Intensive Care Unit

ID	Identification
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JK	Jabatan Kecemasan
M-index	another variant of the h-index that displays h-index per year since first publication
MCO	Movement Control Order
MCP	Multiple country production
MeSH	Medical Subject Headings
MREC	Medical Research & Ethics Committee
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_3	Ozone
OR	Odds ratio
PELT	Pruned Exact Linear Time
PKP	Perintah Kawalan Pergerakan
PM_{10}	Particulate matter less than 10 micrometre in size
$PM_{2.5}$	Particulate matter less than 2.5 micrometre in size
PMM	Predictive Mean Matching
ppm	Parts per million
PSI	Pollutants Standard Index
REML	Residual maximum likelihood
RR	Relative risk
SCP	Single country production
SO_2	Sulphur dioxide
TC	Total citation
UNECE	United Nations Economic Commission for Europe
UNICEF	United Nations Children's Fund
USA	The United States of America
WHO	World health Organization

LIST OF APPENDICES

MEMODELKAN PENCEMARAN UDARA DAN KEDATANGAN KE JABATAN KECEMASAN DALAM KALANGAN KANAK-KANAK YANG MENGHIDAP PENYAKIT PERNAFASAN BERHUBUNG DENGAN FASA PERINTAH KAWALAN PERGERAKAN (PKP) DI MALAYSIA

ABSTRAK

Latar belakang: Peningkatan kerentanan kanak-kanak terhadap pendedahan pencemaran udara dan terhadap kesan buruk pencemaran udara, meningkatkan risiko kematian dan morbiditi mereka. Kesihatan pernafasan kanak-kanak adalah yang paling terjejas dan telah menjadi antara punca utama kedatangan kanak-kanak ke jabatan kecemasan (JK) di seluruh dunia. Berikutan pandemik COVID-19, peningkatan kualiti udara dunia dapat dilihat rentetan pelaksanaan sekatan perjalan di seluruh negeri. Oleh itu, kami merangka empat objektif untuk memodelkan perubahan dalam hubungan antara pencemaran udara dan kedaangan ke JK di kalangan kanak-kanak dengan penyakit pernafasan berhubung fasa Perintah Kawalan Pergerakan (PKP) di dua bandar di Malaysia iaitu 1) Untuk menentukan perubahan dalam tren kedatangan kanak-kanak ke JK; 2) Untuk menentukan perubahan dalam tren kedatangan kanak-kanak ke JK dengan penyakit pernafasan; 3) Untuk menentukan perubahan dalam tren kepekatan pencemaran udara; dan 4) Untuk memodelkan dan membandingkan hubungan antara pencemaran udara dan kedatangan ke JK berkaitan penakit pernafasan di kalangan kanak-kanak merentasi tempoh sebelum, semasa dan selepas PKP di dua bandar di Malaysia.

Kaedah kajian: Kajian ini menggunakan data sekunder dari dua hospital awam di bandar Kota Bharu dan Johor Bahru merangkumi maklumat kedatangan kanak-kanak ke JK selama lima tahun (17 Mac 2017 hingga 17 Mac 2022). Indeks

pencemaran udara, bahan zarah kurang daripada 10μm (PM_{10}), bahan zarah kurang daripada 2.5μm ($PM_{2.5}$), nitrogen dioksida (NO_2), sulfur dioksida (SO_2), karbon monoksida (CO), dan ozon (O_3) merupakan pembolehubah yang dimanipulasikan. Manakala, pembolehubah tindak balas ialah bilangan kedatangan kanak-kanak ke JK serta ciri-ciri lawatan tersebut yang melibatkan kategori triaj, hasil kedatangan ke JK, diagnosa di JK, dan subkategori diagnosa penyakit pernafasan. Kajian ini melibatkan semua kanak-kanak di bawah umur 18 tahun yang memenuhi kriteria kajian. Tempoh kajian dibahagikan kepada tiga tempoh berdasarkan PKP di Malaysia, iaitu pra-PKP (17 Mac 2017 hingga 17 Mac 2020), semasa PKP (18 Mac 2020 hingga 2 Januari 2022), dan pasca-PKP (3 Januari 2022 hingga 17 Mac 2022). Pencemaran udara dan ciri-ciri lawatan kanak-kanak ke JK dibandingkan antara tiga tempoh menggunakan ujian-*t Welch* bagi pembolehubah berangka dan regresi logistik multinomial bagi pembolehubah berkategori. Analisis titik perubahan digunakan untuk mengesan sebarang titik perubahan dalam tren lawatan kanak-kanak ke JK manakala model aditif umum digunakan untuk mengkaji hubungan antara pencemaran udara dan lawatan kanak-kanak ke JK untuk penyakit pernafasan sepanjang tiga tempoh.

Keputusan: Sebanyak 175,737 kedatangan pesakit kanak-kanak telah direkodkan dalam tempoh lima tahun di mana hampir 30% (52,704) daripadanya telah didiagnosa dengan penyakit pernafasan. Semasa PKP, kedatangan kanak-kanak ke JK menurun sebanyak 57.57%. Walaupun kedatangan dengan kategori triaj kuning (OR=1.23, 95% CI: 1.20-1.28, $p<0.001$) dan merah (OR=1.79, 95% CI: 1.69-1.90, $p<0.001$) meningkat, sebaliknya kadar kemasukkan ke hospital telah menurun (OR=0.19, 95% CI: 0.18-0.19, $p<0.001$). Penyakit pernafasan kekal sebagai sebab utama kedatangan kanak-kanak ke JK merentasi ketiga-tiga tempoh. Namun begitu, kami melihat perubahan dalam pola subkategori penyakit pernafasan.

Kemungkinan untuk kanak-kanak yang mendapatkan rawatan di JK semasa tempoh pasca-PKP adalah lebih tinggi bagi penyakit influenza atau radang paru-paru (Kota Bharu: OR=1.43, 95% CI: 1.07-1.91, $p<0.001$; Johor Bahru: OR=1.43, 95% CI: 1.15-1.78, $p<0.001$), manakala ianya lebih rendah bagi penyakit pernafasan yang kronik (Kota Bharu: OR=0.07, 95% CI: 0.05-0.09, $p<0.001$; Johor Bahru: OR=0.06, 95% CI: 0.05-0.07, $p<0.001$). Kepekatan bagi semua bahan pencemar udara mengalami penurunan yang ketara semasa tempoh PKP dan pasca-PKP kecuali kepekatan SO_2 di bandar Kota Bharu untuk kedua-dua tempoh semasa PKP ($t(1626.18) = 6.78$, $p<0.001$) dan pasca-PKP ($t(76.63) = 5.05$, $p<0.001$), serta kepekatan CO di bandar Johor Bahru dalam tempoh pasca-PKP ($t(73.18) = 4.84$, $p<0.001$). Model kami menjelaskan 69.9% (Kota Bharu: $R^2 = 0.62$) dan 53.0% (Johor Bahru: $R^2 = 0.49$) daripada variasi kedatangan kanak-kanak ke JK dengan penyakit pernafasan berdasarkan kepekatan pencemar udara. Di Kota Bharu, hubungan ketara antara penyakit akut jangkitan saluran atas pernfasan dengan PM_{10} semasa tempoh pra-MCO (edf = 6.44, $p<0.001$) telah digantikan dengan hubungan linear yang ketara (edf = 1.00) dengan NO_2, CO dan O_3 dan hubungan kuadratik yang ketara (edf = 2.09) dengan SO_2 bagi tempoh pasca-PKP. Di Johor Bahru pula, walaupun bilangan hubungan yang ketara antara pencemar udara dan subkategori penyakit pernafasan meningkat semasa PKP, hubungan tersebut menjadi tidak ketara dan kebanyakannya kembali ke tahap pra-PKP sewaktu pasca-PKP.

Kesimpulan: Sekatan pergerakan (PKP) semasa pandemik COVID-19 bukan sahaja telah melihatkan peningkatan dalam kualiti udara di dua bandar di Malaysia, malahan juga telah mengubah pola dan sebab kanak-kanak mendapatkan rawatan di JK bagi penyakit pernafasan. Pencemaran udara masih merupakan faktor risiko yang penting untuk penyakit pernafasan dalam kalangan kanak-kanak di Malaysia, dengan

kesan yang berbeza bergantung kepada tempoh dan lokasi pendedahan tersebut. Kajian ini mencadangkan sektor kesihatan awam bagi meningkatkan kesedaran, memperbaiki persekitaran binaan, dan memperkenalkan sistem amaran awal untuk pencemaran udara dan penyakit pernafasan. Lantas, mencapai matlamat penyediaan udara yang bersih kepada semua lapisan masyarakat.

Kata kunci: COVID-19, Perintah Kawalan Pergerakan, Pencemaran udara, Kanak-kanak, penyakit respiratori, Kedatangan ke jabatan kecemasan hospital, Analisa titik perubahan, Model aditif teritlak

MODELLING AIR POLLUTION AND EMERGENCY DEPARTMENT VISITS AMONG CHILDREN WITH RESPIRATORY DISEASES IN RELATION TO PHASES OF THE MOVEMENT CONTROL ORDER (MCO) IN MALAYSIA

ABSTRACT

Introduction: Children's increased vulnerability towards air pollution exposure, and their increased susceptibility to the adverse effects of air pollution, increases their risk of mortality and morbidity. Their respiratory health is the most affected and has been among the top leading cause for emergency department (ED) visits worldwide. Following the COVID-19 pandemic, an improvement of the world's air quality was observed secondary to the implementation of state-wide lockdowns, known as the Movement Control Order (MCO), in Malaysia. Therefore, we construct four objectives to model the changes in the relationship between air pollution and ED visits among children with respiratory diseases in relation to the phases of the MCO in two cities in Malaysia which are 1) To determine the changes in the trend of paediatric ED visit; 2) To determine the changes in the trend of paediatric ED visits with respiratory disease; 3) To determine the changes in the trend of air pollution concentrations; and 4) To model and compare the relationship between air pollution and respiratory-related ED visits among children across the pre, during, and post-MCO periods in two Malaysian cities.

Methodology: We analysed secondary data of children's ED visits from two public hospitals in Kota Bharu and Johor Bahru cities over five years (17 March 2017 to 17 March 2022). Predictor variables included air pollution index, particulate matter less than 10µm (PM_{10}), particulate matter less than 2.5µm ($PM_{2.5}$), nitrogen

dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3). Whereas the response variables are the number of children's ED visits and their characteristics which include the triage category, visit outcome, ED diagnosis, and respiratory diagnosis subtype. The study included all children under the age of 18 who fulfils the selection criteria. The study period was divided into three periods based on the MCO in Malaysia, which are the pre-MCO (17 March 2017 to 17 March 2020), MCO (18 March 2020 to 2 January 2022), and post-MCO (3 January 2022 to 17 March 2022) periods. The trend of air pollution concentration and paediatric ED visits' characteristics were compared between the three periods using Welch *t*-tests for numerical outcomes and multinomial logistic regressions for categorical outcomes. Changepoint analysis was used to detect any changepoints within the trend of paediatric ED visits whereas generalized additive models were used to examine the relationship between air pollution and children's ED visits for respiratory diseases across the three periods.

Result: A total of 175,737 visits were recorded over the five years where nearly 30% (52,704) were diagnosed with a respiratory disease. During the MCO, the children's ED visits decreased by 57.57%. An increase in the proportion of yellow (OR=1.23, 95% CI 1.20 to 1.28, $p<0.001$) and red (OR=1.79, 95% CI 1.69 to 1.90, $p<0.001$) triage categories was observed in contrast to a decrease in the proportion of hospitalized cases (OR=0.19, 95% CI 0.18 to 0.19, $p<0.001$) during the MCO period. Although respiratory diseases remain as the main reason for ED visits across all three periods, we observed changes in the trend of the respiratory subtypes. The odds of being diagnosed with influenza and pneumonia increased significantly during the post-MCO period (Kota Bharu: OR=1.43, 95% CI 1.07 to 1.91, $p<0.001$; Johor Bahru: OR 1.43, 95% CI 1.15 to 1.78, $p<0.001$) whilst the odds for chronic lower

respiratory disease decreases (Kota Bharu: OR=0.07, 95% CI 0.05 to 0.09, p<0.001; Johor Bahru: OR=0.06, 95% CI 0.05 to 0.07, p<0.001). All air pollutants experienced a significant decline during the MCO and post-MCO periods except for SO_2 concentration in the Kota Bharu city for both the MCO (t(1626.18) = 6.78, p<0.001) and post-MCO periods (t(76.63) = 5.05, p<0.001) and CO concentration in Johor Bahru city during the post-MCO period (t(73.18) = 4.84, p<0.001). Our model explained 69.9% (R^2 = 0.62) and 53.0% (R^2 = 0.49) of the variation in paediatric respiratory ED visits in Kota Bharu and Johor Bahru based on the air pollution concentrations, respectively. In Kota Bharu, PM_{10} is significantly associated with acute upper respiratory infections during the pre-MCO period (edf = 6.44, p<0.001) but was no longer significantly associated in the post-MCO period. In Johor Bahru, although the number of significant relationships between individual air pollutants to the different respiratory subtypes increased during the MCO period, the significance of these relationships diminishes during the post-MCO period, and the number of significant relationships becomes less compared to the pre-MCO period.

Conclusion: The COVID-19 lockdown improved air quality and altered the patterns and causes of paediatric respiratory ED visits in two Malaysian cities. Thus, highlighting air pollution as a significant risk factor for respiratory diseases in children, in Malaysia, with different effects depending on the exposure type and duration. This study suggests some public health recommendations to raise awareness, improve the national pandemic preparedness plan, and introduce early warning systems for air pollution and respiratory diseases in the ED.

Keywords: COVID-19 lockdown, Movement Control Order, Air pollution, Children, Respiratory disease, Emergency department visits, Changepoint analysis, Generalized additive model

~~1.~~CHAPTER 1

INTRODUCTION

1.1 Background

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. It was first identified in Wuhan, China, and has subsequently spread globally, with the World Health Organization (WHO) declaring it a pandemic in March 2020. The virus attacks the respiratory system causing infected people to portray a broad spectrum of symptoms, from being asymptomatic to mild respiratory disease, severe respiratory failure, and even death (WHO, 2022). With nearly 400 million confirmed cases and more than 5 million deaths, health systems worldwide responded by implementing state-wide lockdowns, or similarly known as the Movement Control Order (MCO), in Malaysia. The MCO was implemented as a measure to control the pandemic by flattening the epidemiological curve, thus allowing time for the health system to respond efficiently (Violato et al., 2021). Secondary to the MCO, an unintentional upside was observed from this pandemic which is the reduction in air pollution (Hasnain *et al.*, 2021; Othman and Latif, 2021; Zangari *et al.*, 2020).

Air pollution is one of the largest and most geographically dispersed health and environmental hazards that have posed an indiscriminate threat to the entire world's population for the past two millennia. According to WHO estimates, 286,000 children under the age of 15 died in 2016 as a result of exposure to unhealthy levels of ambient air pollution (WHO, 2018). In addition to being responsible for 11.56% of global deaths, it also ranks as one of the leading contributors to the global burden of disease in 2019 (Ritchie and Roser, 2021). Exposure to air pollution, especially during the sensitive period of brain, lungs, and organs development in the prenatal and early life stages, is known to decrease lung function, can cause acute lower respiratory tract infections, and potentially lead to asthma, cancer, and obesity in children (An *et al.*, 2018; Brugha and Grigg, 2014; Garcia *et al.*, 2021; Schraufnagel *et al.*, 2019). Categorically, younger children are more likely to stay indoors, where they may be exposed to indoor air pollution through household burning of coal, biomass, and kerosene for cooking or heating, whereas older children generally spend more time outdoors engaging in physical activities or socializing in potentially polluted air. Children's small stature exposes them to ground-level air pollution where some pollutants reach peak concentration. Children also have a higher rate of respiration and a larger skin surface area to body mass ratio compared to adults allowing for increased absorption or air pollutants. These combined physiological, behavioural, and environmental factors increase a child's vulnerability and susceptibility to the negative impacts of air pollution on health, leading to a high burden of mortality and morbidity (WHO, 2018).

Approximately 15 out of 100 children visited the emergency department (ED) at least once a year, making up nearly 40% of the overall visits (Goto *et al.*, 2017; Statista, 2021). Most of these visits were discharged from the ED, with a ratio of one hospital admission out of every 14 to 20 ED visits, with respiratory diseases being among the top reasons for their visits (McDermott *et al.*, 2018; Winquist *et al.*, 2012). Studies on the association of air pollution to ED visits among children have remained contradictory in the literature, with a positive association being more apparent for respiratory diseases and disease of the ear, nose, and throat, conjunctivitis, and mental health disorders (Abrutzky *et al.*, 2017; O.Lukina *et al.*, 2021; Szyszkowicz *et al.*, 2018; Szyszkowicz *et al.*, 2020; Xiao *et al.*, 2016).

1.2 Problem statement and study rationale

The COVID-19 pandemic necessitated the implementation of the MCO, leading to a notable reduction in air pollution levels across various regions. While previous studies have highlighted the positive impact of such reductions on overall air quality, there remains a significant knowledge gap regarding the specific effects on children's respiratory health during this unique period. Understanding the relationship between air pollution reduction resulting from the COVID-19 MCO and its potential benefits to children's respiratory health is imperative for devising evidence-based strategies to mitigate the adverse impacts of air pollution on vulnerable paediatric populations.

Therefore, the present study aims to investigate the changing landscape of ambient air pollution in Kota Bharu, Kelantan, and Johor Bahru, Johor, cities during the COVID-19 MCO in Malaysia. The cities represented the northeastern and southern regions of peninsular Malaysia and has the highest level of air pollution within their respective regions. Despite that, during the MCO, a substantial reduction in nitrogen dioxide (NO_2) and carbon monoxide (CO) were observed, whilst particulate matter (PM_{10} and $PM_{2.5}$) concentrations showed no significant changes (Othman and Latif, 2021). These similar changes allow for reduction in bias when comparing both these urban areas. Likewise, children made up 26.6% and 26.3% of Kota Bharu’s and Johor Bahru’s population, which are 13% and 8% of the total Malaysian children’s population, respectively (Department of Statistics Malaysia, 2023). The study will examine how this reduction in ambient air pollution influences paediatric emergency department visits for respiratory diseases.

In contrast to prior studies that often focused on children under the age of five with hospital admission or mortality as health outcomes, this study will broaden its scope by selecting children under the age of 18 and focusing on emergency hospital visits. This approach allows for the inclusion of a wider spectrum of respiratory disease severity in the analysis.

The positive impact of the MCO and similar public health initiatives on global air pollution demonstrates that, contrary to popular belief, reducing ambient air pollution is a task that can be accomplished. Overall, this research seeks to shed light on the effectiveness of ambient air pollution reduction measures in mitigating the burden of respiratory diseases on children and to inform policy decisions aimed at improving air quality and safeguarding children's health. Additionally, the findings will contribute to strengthening the current emergency department's early warning system for paediatric respiratory disease preparedness.

1.3 Research questions

1. What is the trend and pattern of emergency department visits due to respiratory disease among children in two cities in Malaysia?
2. What is the estimated impact of the COVID-19 MCO on air pollution concentration in two cities in Malaysia?
3. How do the changes in air pollution concentration during the COVID-19 MCO influence the relationship between air pollution and paediatric emergency department visits for respiratory disease?

1.4 Research hypothesis

1. There is a significant difference in the trend of paediatric emergency department visit during the Movement Control Order in two cities in Malaysia.

2. There is a significant difference in the trend of paediatric emergency department visit for respiratory diseases during the Movement Control Order in two cities in Malaysia
3. The air pollutant levels significantly decrease during the Movement Control Order in two cities in Malaysia
4. There is significant relationship between air pollution and paediatric emergency department visits for respiratory disease across the pre, during, and post Movement Control Order in two cities in Malaysia.

1.5 Objectives

1.5.1 General

This study aims to model the changes in the relationship between air pollution and emergency department visits among children with respiratory diseases in relation to the phases of the Movement Control Order in two cities in Malaysia.

1.5.2 Specific

1. To determine the changes in the trend of paediatric emergency department visit in two cities in Malaysia in relation to the phases of the Movement Control Order.
2. To determine the changes in the trend of paediatric emergency department visits with respiratory disease in two cities in Malaysia in relation to the phases of the Movement Control Order.
3. To determine the changes in the trend of air pollution concentrations in two cities in Malaysia in relation to the Movement Control Order.

4. To model and compare the relationship between air pollution and respiratory-related emergency department visits among children across the pre, during, and post-MCO periods in two Malaysian cities.

~~2.~~CHAPTER 2

LITERATURE REVIEW

All the literature searches on ambient air pollution and hospital emergency department visits were widely done using search engines such as PubMed, COCHRANE, Science Direct, Scopus, and Google Scholar. Various searching strategies were applied, such as a combination of terms with Boolean operators (AND or OR). The entire literature searches published from 2011 to 2023 were included. Keywords used were COVID-19, air pollution, carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter less than 10μm (PM_{10}), particulate matter less than 2.5μm ($PM_{2.5}$), children, respiratory disease, and emergency department (ED) visit with their respective MeSH terms.

~~1.6~~2.1 Air pollution and its sources of emissions

Air pollution is defined as contamination of the indoor or outdoor (ambient) environment by the presence of one or more chemical, physical, or biological substances at a concentration, or for a duration, above their natural levels, with the potential to modify the natural characteristics of the atmosphere, or produce an adverse effect in human health (IARC, 2016; WHO, 2021). Common contaminants include NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$, and volatile organic compounds. Except for volatile organic compounds, these substances are monitored by the Department of Environment (DOE) to calculate the air pollution index (API) in Malaysia (Figure 2.1) and are divided into five categories: good (0 to 50), moderate (51 to 100), unhealthy (101 to 200), very unhealthy (201 to 300), and hazardous (> 301) (Department of Environment, 2021). Calculation of the API for a given period is determined by the average concentration calculated (sub-index values) for all five pollutants included in the API System. The maximum sub-index of all five pollutants is then selected as the API with the relevant health effect category, and actions to be taken were reported for the specific responsible air pollutants.

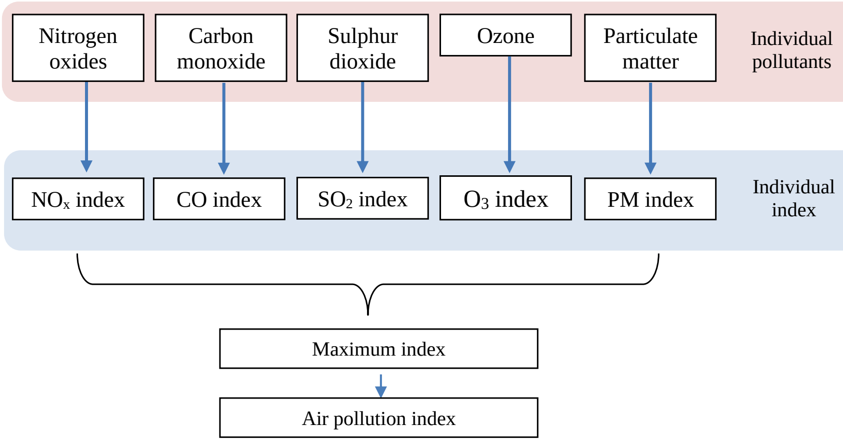
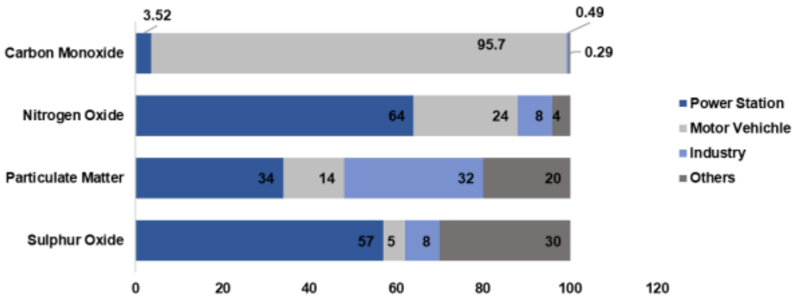


Figure 2.1: Air pollution index value calculation

The API is used to measure the degree of pollution in the ambient environment. The ambient environment is anything external to a constructed and completely contained facility, from the ground up to several miles above the surface of the Earth. The source of ambient air pollution can be divided into natural and anthropogenic origins. Between the two, anthropogenic emissions are relevant globally since control measures can be implemented through regulations and voluntary initiatives, leading to a decrease in pollutants. Examples of anthropogenic sources include motor vehicle emissions and stationary power plants, which account for most ambient air pollution, followed by industrial and agricultural emissions (IARC, 2016). Emissions from fossil fuel combustion in power plants and motorized vehicles are the most significant contributors to the ambient air pollution in Malaysia.

For example, power plants contributed more than half of the total nitrogen oxide and sulphur dioxide emissions, whereas motor vehicles contributed the majority of carbon monoxide (95.7%) (Figure 2.2).



(Source: DOE, 2019)

Figure 2.2: Breakdown of sources of key air pollutants in Malaysia

Southeast Asian nation Malaysia was ranked third in pollution emissions, after Thailand and Indonesia. Contrary to earlier perceptions, which held that air pollution is a local problem limited to close emission sources or urban areas, the trend of rising transboundary air pollution and seasonal haze has had a direct influence to local air quality, raising serious health concerns.

The indoor environment is a mix of both outdoor and indoor air pollutants. Outdoor pollutants emitted from vehicular traffic and industrial activities infiltrated the indoor environment through natural or mechanical ventilation. Whereas common sources of indoor air pollutants are burning of fuels, wood, or tobacco, emissions from construction materials and furnishings, central cooling or humidification systems, electronic appliances, household cleaning products, pets, and the occupant actions including smoking and painting (Cincinelli and Martellini, 2017). The indoor-outdoor ratio is a common parameter used to quantify the relative strength of indoor air pollutant concentration with respect to the immediate outdoor environment. Although the result is diverse within the literature, more than two thirds of the published literature on combined indoor and outdoor air pollution studies show that indoor air pollutant concentration is higher than its external environment (Leung, 2015). In general, a higher indoor-outdoor ratio implies the presence of robust indoor activities such as cooking and smoking, whilst a lower indoor-outdoor ratio implies fewer sources of emission and good building insulation (Leung, 2015).

~~1.7~~2.2 Implementation of the Movement Control Order (MCO) in Malaysia

Following the WHO's declaration of the COVID-19 pandemic in 2020, numerous state-level initiatives have been put in place by nations worldwide to stop the disease's spread. State-wide lockdowns were one of the actions adopted, which included limiting population movement, prohibiting international travel, and ordering the closure of businesses, industries, the government, and even educational institutions. Malaysia similarly implemented a nationwide lockdown, known as the Movement Control Order (MCO), on March 18, 2020, following a rapidly rising number of locally transmitted COVID-19 cases.

The MCO was implemented under the Control and Prevention of Infectious Diseases Act 1988 and the Police Act 1967 and is a type of restriction that completely prohibits people from leaving their neighbourhood, including engaging in normal daily outdoor activities or social gatherings nationwide (Othman and Latif, 2021). International travels for all Malaysian citizens, foreign visitors, and tourists were totally banned through either land, sea, or air routes. Motor vehicle usage was drastically reduced further during this period with the closure of all education facilities and government premises except those involved in essential services such as medical facilities and the police department. Closure of private premises, including industrial facilities, was also implemented. Restrictions were lifted in phases from total MCO, progressing to conditional MCO and recovery MCO depending on the COVID-19 landscape in Malaysia. On January 3, 2022, the MCO was completely lifted after Malaysia achieved a daily average of fewer than 500 COVID-19 cases, a stabilized public healthcare system with an appropriate level of ICU bed utilization, and vaccination coverage of more than 60% of the population with at least two doses of the COVID-19 vaccine.

~~1.8~~2.3 Pre-, during, and post-Movement Control Order disparity in air pollution

A recent overview of Malaysia's air quality shows that it generally has better air quality compared to its neighbouring countries such as Indonesia, Thailand, and Vietnam (IQAir, 2023). The air quality, based on the API system, are mostly moderate with occasional unhealthy and very unhealthy levels during haze episodes secondary to the occurrence of forest and bush fires (Department of Environment, 2019). Individual air pollutant levels were recorded to be within the Malaysia Ambient Quality Standard 2020's guidelines with positive improvements observed especially with the change in using better fuel quality, EURO2m, in the country, starting from September 2009 (Department of Environment 2019). However, these levels are still far from the targeted air quality levels listed in the WHO Air Quality Guidelines. Additionally, with the updated guideline in 2021, more drastic measures will be required to achieve the global target (Table 2.1).

Table 2.1 Comparison of the Malaysia Ambient Quality Standard (2020) and the WHO Air Quality Guidelines (2005 and 2021)

Pollutants	**Averaging time**	**Malasia Ambient Quality Standard (2020) (μg/m^3)**	**WHO Air Quality Guidelines (2005) (μg/m^3)**	**WHO Air Quality Guidelines (2021) (μg/m^3)**
PM_{10}	1 year	40	20	15
	24 hours	100	50	45
$PM_{2.5}$	1 year	15	10	5
	24 hours	35	25	15
SO_2	1 hour	250	-	-
	24 hours	80	20	20
NO_2	1 year	-	40	25
	1 hour	280	200	100
	24 hours	70	-	
Ground level O_3	1 year	180	-	-
	8 hours	100	100	100
CO	1 year	30	-	-
	8 hours	10	-	-
	24 hours	-	-	7

In the year 2019, it is estimated that the overall total emission load of air pollutants was 2,235,141 metric tonnes of CO, 925,370 metric tonnes of NO_2, 270,270 metric tonnes of SO_2, and 27,178 metric tonnes of particulate matter (PM). Primary contributors to air pollution in Malaysia encompass road transportation, power production, and industrial operations, among other sources. Notably, transportation accounts for roughly 70% of air pollution emission. Hence, the decrease in road transportation and closure of industrial operations following the MCO have removed the major sources of air pollution in Malaysia. This positive environmental benefit from the MCO is evident in the study by Othman and Latif 2021 where significant declines in some air pollutants in major Malaysian cities were observed. On a global scale, reduction in global air pollution, particularly NO_2 (23 to 37% reduction), followed by PM_{10} (14 to 20% reduction), SO_2 (2 to 20% reduction), $PM_{2.5}$ (7 to 16% reduction), and CO (7 to 11% reduction) was also observed (Al-Abadleh *et al.*, 2021; Liu *et al.*, 2021; Stratoulias and Nuthammachot, 2020). However, to date, there is yet to be published a time series analysis that extends the time period of observation beyond the MCO period to the post-MCO period.

~~1.9~~2.4 The interplay between environmental variables and air pollution

Environmental factors that affect the emission, production, dispersion, and concentration of air pollutants include greenhouse gases, weather patterns, and urbanization. For instance, greenhouse gases in the troposphere absorb sunlight that traps heat within the atmosphere, which in turn affects atmospheric circulation, cloud formation, precipitation amounts, and evaporation rates (Climate and Clean Air Coalition, 2021). Climate change resulting from these greenhouse gases is evident with a notable increase in global temperatures, changing global precipitation patterns, melting of ice and snow, and rising global average sea level (Patella *et al.*, 2018). These adverse meteorological conditions have been recorded to impact the concentration of air pollutants. For example, a study by Liu *et al.* (2020) in China determined that most air pollutant concentrations were significantly negatively correlated with wind speed, temperature, precipitation, and relative humidity. Their multiple logistic regression analysis found that the concentration of $PM_{2.5}$, PM_{10}, SO_2 and NO_2 decreased by 0.16, 0.22, 0.12 and 0.12 μg/m^3 for every 1 m/s increase in average wind speed, respectively. In contrast, although an increase in temperature had a significant and negative effect on SO_2 concentration (SO_2 decreased by 0.85 μg/m^3 for every 1°C increase in the average temperature), a positive effect on O_3 concentration was observed (O_3 concentration increased by 2.63 μg/m^3 for every 1°C increase in the average temperature).

Differential exposure is experienced by the urban and rural residents with the low- and middle-income countries especially within the WHO Western Pacific and

Southeast Asia regions experiencing the highest-burden on health due to air pollution (WHO, 2021). Disparities between urban and rural environments are evident in the literature with varied results (Li *et al.*, 2018; Zhao *et al.*, 2021). Compared to their counterparts in rural areas, urban dwellers typically enjoy favourable socioeconomic conditions, better nutritional status, and more accessible access to medical services (Li *et al.*, 2018; Richman *et al.*, 2019). However, the rapidly expanding city is vulnerable to local space-time volatility in urban air pollution concentrations due to a mix of land usage, high-density population, and meteorological conditions (Adams and Kanaroglou, 2016; Li *et al.*, 2020). Despite having fewer stationary sources of pollution, rural areas are subjected to higher levels of air pollutants transported hundreds of miles away from their sources by the wind (Li *et al.*, 2020).

~~1.10~~2.5 Children's susceptibility to the health impacts of air pollution

Children's increased life expectancy compared to adults provides a longer timeframe for latent disease mechanisms to manifest and impact their well-being. Due to their rapid bodily development, particularly in their lungs, they are more susceptible to inflammation and other harm caused by pollutants. While in the womb, they are at risk from pollutants their mothers are exposed to. Even prior to conception, the foetus can face latent risks from pre-conception exposure. Post-birth, children often lack the agency to alter their environment, with the youngest unable to simply leave a smoke-filled room.

Along with the external environmental factors, a child's internal makeup also significantly influences how susceptible they are to the negative effects of air pollution on their health. The genetic makeup of the child, which includes factors like gender and age, or the physiological response to external stresses like illness, food, and psychological stress, can both contribute to host susceptibility (Kodavanti, 2019). For example, physiologically, children are exposed to pollutants for longer periods of time at higher quantities than adults because they breathe more rapidly and dwell closer to the ground (WHO, 2018). Behaviourally, older children may spend more time outside playing or engaging in physical activities in potentially contaminated air.

The ramifications of their exposure, whether through inhalation, ingestion, or prenatal conditions, can result in lifelong health issues and burdens. Yet, these children rely entirely on the adults, to safeguard them from the exposure to unhealthy air. Their vulnerability necessitates a concerted and coordinated approach to reduce air pollution that transcends regional and international boundaries. By improving children's health, far-reaching positive effects on the future can be achieved in several significant ways including human capital development, educational achievement, and reduced healthcare burden. Thus, fostering a cycle of positive outcomes that benefit individuals, communities, and societies as a whole.

~~1.11~~2.6 Presentation to the emergency department attributable to air pollution

Short-term exposure to a high concentration of air pollution has been reported to have significant acute health effects leading to presentation to the emergency department. For example, a study in Singapore found no association between the Pollutants Standard Index (PSI) and total ED visits to public hospitals in Singapore. However, for every 30-unit increase in PSI, a slight increase in ED visits for respiratory conditions was observed (RR = 1.023, 99.2% CI 1.011 to 1.036) (Chan *et al.*, 2020). In addition, a study in the state of Georgia, USA, found that secondary pollutants are strongly associated with an increase in bronchitis (OR=1.090, 95% CI 1.050 to 1.132), pneumonia (OR=1.085, 95% CI 1.047 to 1.125), and otitis media

(OR=1.059, 95% CI 1.042 to 1.077), while O_3, NO_2, and SO_2 were observed to be associated with an increase in emergency department visits among children for an exacerbation of asthma (OR=1.068, 95% CI 1.04 to 1.097) (Xiao *et al.*, 2016). Although disease-specific associations for cardiovascular events, conjunctivitis, and acute mental health deterioration of known patients are also observed in the literature, stratified analysis based on age is limited (Akbarzadeh *et al.*, 2018; Szyszkowicz *et al.*, 2016; Szyszkowicz *et al.*, 2020; Wang *et al.*, 2019).

~~1.12~~2.7 Children's respiratory health and the ambient air pollution

Exposure to polluted air can affect health in the short and long term. More than 93% of children are exposed to particulate matter ($PM_{2.5}$) levels that exceed the WHO recommended guidelines. A cross-sectional study of children in Klang Valley and Sarawak shows that short-term exposure to ambient air pollution increases the risk of the respiratory disease up to 8 days after exposure, with a 7-day lag from exposure to disease presentation (UNICEF Malaysia, 2021). Compared to Kuching, SO_2 and O_3 were significantly associated with increased respiratory hospital admissions in Klang Valley. Only PM_{10} was significantly associated with increased total admissions for respiratory diseases among children in Kuching (UNICEF Malaysia, 2021).

Disease-specific analysis in six European countries shows that PM_{10} (adjusted OR PM_{10} = 1.76, 95% CI 1.00 to 3.90, p=0.051) and traffic exposure (adjusted OR NO_2 = 1.30, 95% CI 1.02 to 1.65, p=0.024) were significantly associated with an increased risk of pneumonia (MacIntyre *et al.*, 2014). A study in 625 cities worldwide shows that, on average, an increase of 10µg per cubic meter in the 2-day moving average of PM_{10} concentration was associated with increases of 0.44% (95% CI 0.39 to 0.50) in daily all-cause mortality, 0.36% (95% CI 0.30 to 0.43) in daily cardiovascular mortality, and 0.47% (95% CI 0.35 to 0.58) in daily respiratory mortality (Liu *et al.*, 2019). These associations remained significant after adjustment for gaseous pollutants, with stronger associations observed in locations with a lower annual mean of particulate matter concentrations and higher annual mean temperatures. A review by Ibrahim *et al.* (2021) reported that ambient air pollution is associated with respiratory-related mortality in Asia's lower- and middle-income countries.

~~1.13~~2.8 Changes in the health effects of air pollution and paediatric respiratory diseases following public health interventions during the COVID-19 pandemic

According to a local study by Othman and Latif (2021), the estimated hazard quotient of air pollution in Malaysia decreased after the implementation of the MCO. The only two air pollutants with higher hazard quotient values during the MCO compared to the pre-MCO period were $PM_{2.5}$ and O_3. A hazard quotient is a measure used in environmental health assessments to estimate the potential adverse effects of exposure to a particular pollutant. Therefore, the reduction in hazard quotient of air pollution during the MCO implies a decrease in the potential risk or harm posed by air pollutants to human health.

Regarding paediatric ED visits, 11 Canadian hospitals have shown a considerable decrease in the overall number of paediatric ED visits during the early stages of the epidemic. However, compared to the pre-pandemic period, the proportion of emergency patients is higher, while the number of non-urgent cases is lower during the early stages of the pandemic (Finkelstein *et al.*, 2021). The stringency of the government’s response in implementing public health interventions also play a role in the number of children visiting the ED. A multicentre study in

Korea observed that for every 10-point increase in the Government Response Stringency Index (GRSI) during the COVID-19 pandemic, there was a 15.1% decrease in monthly paediatric ED visits, where the GRSI is a composite measure based on nine social distancing indicators and ranges from 0 to 100 (Choi *et al*., 2021).

Changes in paediatric respiratory health was also documented in the current literature, with the decrease in paediatric respiratory diseases being mostly attributed to the population movement restrictions that were implemented. However, a study in Philadelphia, USA, observed that despite the reduction in the number of ED visits for asthma exacerbation, the number of outpatient prescriptions for outpatient asthma medications remain the same after the implementation of public health interventions (Taquechel *et al*., 2020). An exception was seen for the number of systemic steroid prescription which reduced by 83%, implying to a decrease in severity and duration of illness of asthma exacerbations among children. Alterations in the trend of respiratory infections were also observed where the number of rhinovirus infections decreased in Philadelphia and the United Kingdom but subsequently increased in the latter, following re-opening of schools. Infections by respiratory syncytial virus (RSV) was observed outside its usual season leading to an inter-seasonal increase in July of 2021 and a higher proportion of RSV infections compared to other common childhood respiratory viruses, including influenza A (18.82%), influenza B (18.35%), adenovirus (27.26%), and others (1.83%) (Lumley et al., 2022; Ye and Wang, 2022).

~~1.14~~2.9 Modelling the effect of COVID-19 on the association between air pollution and paediatric respiratory diseases

Any biological or non-biological system can be modelled mathematically. Mathematical models describe a system using mathematical terms and tools to understand it better, investigate the interactions between its various parts, and forecast its behaviour (Ding *et al.*, 2021). The earliest record of mathematical modelling used in infectious disease management was during the 18th century when Daniel Bernoulli (1700 to 1782) modelled the expected increase in life expectancy if smallpox could be eliminated as a cause of death to support the variolation of smallpox (Brauer, 2017). Since then, data analysis and modelling of the different elements of disease spreads have become crucial in assisting epidemiologists in understanding the biological scenario for epidemics of infectious diseases and planning for control measures. Mathematical models are generally divided into dynamic models and statistical models. Dynamic models are then further subdivided into compartmental and individual-based models (Ding *et al.*, 2021).

A dynamic model accounts for the time-dependent changes in disease transmission. In the recent COVID-19 pandemic, compartmental models such as the SIRS model (Susceptible-Infectious-Recovered-Susceptible) and its variations have been used to study the evolution of COVID-19 and the need for different levels of quarantine or movement restrictions to flatten the epidemiological curve (Kumar *et al.*, 2022). Traditionally, these models require detailed data on population movement that may not be available. Dynamic models, however, are now built primarily on parameter assumptions rather than necessarily taking into account the real-world data to be modelled, which allows for data harvesting from verified data sources such as the WHO and Worldometer (Adeniyi *et al.*, 2020). As these models consider the infectious character of COVID-19, including the size of the population and the indirect protection effects of vaccination, they can be used to formulate prevention measures that impact the COVID-19 incidence in the population, such as the MCO (Welte *et al.*, 2005).

On the other hand, statistical models are more applicable in determining prevention measures that have no impact on the COVID-19 incidence in the population. An example include the Auto-Regressive Integrated Moving Average model (ARIMA) that was used to predict the progress of COVID-19 based on its past values (Wang *et al.*, 2022a). Statistical models such as the generalized additive model (GAM) and the distributed lag non-linear model (DLNM) were used to describe the relationship between an outcome (for example, death by COVID-19) and an explanatory variable (such as age, underlying co-morbidity, and environmental factors), thus estimating an 'unadjusted' or 'crude' effect of these variables on the outcome without considering other factors (Ding *et al.*, 2021; Singh, 2021; Zhao *et al.*, 2022; Zhou *et al.*, 2022). Although statistical models assume a constant force of the COVID-19 infection which undermines the indirect protection effects of the various public health measures implemented, they can quickly identify the risk factors at low cost and are much easier to be interpreted for rapid decision-making during a pandemic (Welte *et al.*, 2005).

Another statistical model, the changepoint model, was used in previous studies in India, China, and Italy in an attempt to understand the directional change of the COVID-19 pandemic by assessing and validating the trends of COVID-19 by estimating its change points in time (Jiang *et al.*, 2023; Kumar *et al.*, 2022; Stufano *et al.*, 2021). Changepoint analysis is a statistical technique used to identify points in time where the properties of a time series undergo an abrupt change. The changes can either be within the probability distribution of a time series or its stochastic process. In the field of epidemiology, changepoint analysis was considered to have the potential to detect disease outbreaks and aid in decision-making during response management (Texier *et al.*, 2016). It is a non-parametric technique, so it is independent of any hypotheses about distributions. A change point method primarily identifies the place in time-ordered observations where the change has occurred significantly. The piecewise linear trend model naturally divides the data into disjoint segments with approximately the same growth rate and assumes the presence of at least one change point with parameters similar within each segment and different without (Texier *et al.*, 2016).

The **EnvCpt** package in the R programming language is an extension of the **changepoint** package that serves as a tool to automatically select models and diagnostics for changepoint analysis. Although it was originally designed for use with climatic and environmental data, it ultimately found use with a variety of other time series data. Compared to other packages available, it has a faster processing speed and the ability to fit 12 different models simultaneously to detect change points in trends, mean and variance, and autocorrelation models, whilst also fitting models without change points (Lindeløv, 2020). The number of change points is automatically inferred, and an uncertainty index through confidence intervals is also provided. Additionally, the **EnvCpt** gives log-likelihoods for each model that has been penalized by the Bayesian information criterion, allowing for model evaluation and comparison.

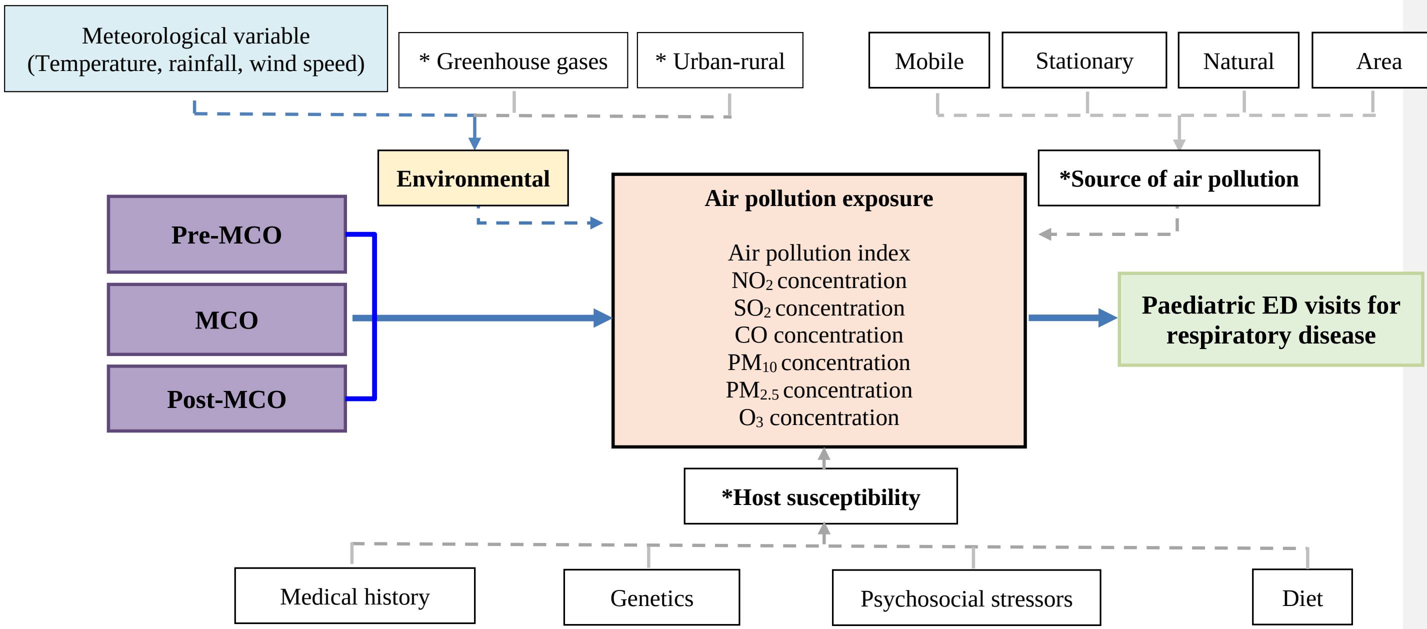
Research on air pollution during the COVID-19 pandemic generally uses statistical modelling that broadly falls into three broad research questions which are: (1) What is the impact of MCO on air pollution concentrations?; (2) How does exposure to air pollution impacts the transmission and susceptibility of getting COVID-19?; (3) What is the association between air pollution exposure to the severity of COVID-19? (Li *et al.*, 2022; Liu *et al.*, 2021; Othman and Latif, 2021; Stufano *et al.*, 2021; Xu *et al.*, 2022; Zhou *et al.*, 2022). Other health impacts, such as hospitalization and infectious respiratory disease incidences, were also studied to a smaller degree (Wang *et al.*, 2022a; Wang *et al.*, 2022b; Wright *et al.*, 2022). Two common models used in disease modelling in environmental epidemiology are GAM and DLNM, as they have the advantage of modelling non-linear associations that are apparent with environmental factors. DLNM is used to estimate the relationship between an exposure and a response over time when the effect of the exposure is both non-linear and delayed. A challenge shared by all distributed-lag models is the decision of lag length and the model selection for covariates, as the covariates themselves can also be DLNMs, especially in time-series studies of air pollution (Gasparrini *et al.*, 2010). The major problems with GAMs are that they tend to overfit and are restricted to be additive which makes it challenging to incorporate the effects of numerous significant interactions (Ravindraa *et al.*, 2019). To get around this, the model needs to manually incorporate the addition and interaction terms. Despite these limitations, both models been have shown to perform well at degrees of freedom of six and 12 when investigating the relationship between air pollution and respiratory disease (Karadağ *et al.*, 2021). A previous study observed that although DLNMs perform slightly better than GAMs in all respiratory disease outcomes, GAMs performs better estimations when the daily number of the event is small and shows better predictions with lower standard errors overall (Karadağ *et al.*, 2021).

~~1.15~~2.10 Conceptual framework

The literature review identified several impacts of the COVID-19 MCO on air pollution and its cascading effects towards emergency department visits among children. Other factors that influence the vulnerability of a child towards air pollution can broadly be categorized as individual susceptibility and risk of exposure. Individual susceptibility includes age, gender, immunity status, and socioeconomic status. The risk of exposure can further be subdivided into the distance to air pollution sources and environmental variables. Environmental variables include urban-rural areas, greenhouse gases, and meteorological variables such as temperature, wind speed, and rainfall.

Pre-, during, and post-MCO periods represent the temporal factor to be studied. For individual susceptibility, children, referring to patients aged under 18 years, will be the only factor considered in the study. Whereas for environmental factors, only the temperature, rainfall, and wind speed data will be included as confounding factors. Other individual susceptibility factors, environmental factors, and the distance to sources of air pollution will be beyond the scope of this study.

In this study, the outcome of interest is the relationship between air pollution and children's visits to the emergency department for respiratory disease. The relationship between air pollution and emergency department visits among children for respiratory disease will be modelled and compared between the pre-, during, and post-MCO periods. Confounding factors include daily temperature, daily rainfall, and daily wind speed. The conceptual framework is depicted in (Figure 2.3).



* Variables that are not included in this study

MCO: Movement Control Order
Direct effect of variables
Confounding variables
Confounding variable included in the study

Figure 2.3: Conceptual framework of COVID-19 lockdown affecting air pollution exposure and the subsequent paediatric emergency department visits in Malaysia confounded by environmental, distance to source, and host susceptibility factors