UNIVERSITI PUTRA MALAYSIA

# *A STUDY OF METEOROLOGICAL FACTORS ASSOCIATED WITH COVID-19 CASES IN SELANGOR, MALAYSIA*

TAN YI HUAN

lp
FPSK2 2022 41

# A STUDY OF METEOROLOGICAL FACTORS ASSOCIATED WITH COVID-19 CASES IN SELANGOR, MALAYSIA

**TAN YI HUAN**

**A PROJECT PAPER SUBMITTED AS PARTIAL REQUIREMENT FOR THE DEGREE OF BACHELOR OF BIOMEDICAL SCIENCES WITH HONOURS**

**DEPARTMENT OF BIOMEDICAL SCIENCES**
**FACULTY OF MEDICINE AND HEALTH SCIENCES**
**UNIVERSITI PUTRA MALAYSIA**

**2022**

© COPYRIGHT UPM

# ABSTRACT

## A Study of Meteorological Factors Associated with COVID-19 Cases in Selangor, Malaysia

***Tan Yi Huan[a], Cheah Yoke Kqueen[a], Eliani Ezani[b], Anita Abd Rahmanc, Hasni Idayu Saidi[a]***

*[a]Department of Biomedical Sciences, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia*

*[b]Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia*

*[c]Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia*

**Introduction:** Several studies have examined the relationship between meteorological factors and COVID-19 infection. It has been discovered that different climates in different locations have a different impact on COVID-19 cases. Therefore, it is essential to establish a location-specific study of meteorological factors and COVID-19 cases. Local researchers in Malaysia have studied the relationship between meteorological factors and COVID-19 cases in Kuala Lumpur and Malaysia as a whole. Such studies must also be established in the most populous state in Malaysia, Selangor. **Objective:** This study aims to evaluate the relationship between the meteorological factors and the daily new COVID-19 cases in Selangor, Malaysia. Dew point, temperature, relative humidity, precipitation, and wind speed are the meteorological factors investigated in this study. **Methodology:** Kendall rank correlation analysis and cross-correlation analysis were used to control for collinearity and lag effects. Negative binomial (NB) model and zero-inflated negative binomial (ZINB) model were used to estimate the effect of meteorological factors on daily new COVID-19 cases, taking into account the overdispersion and zero-inflation of the dependent variable. All significant meteorological factors were fitted in the model. The best model was selected based on Akaike information criterion (AIC). Backward elimination is then performed in the selected multivariable model to select the most significant meteorological factors and optimize the model. **Results:** ZINB provides the best fitting with the lowest AIC value. Temperature, relative humidity, dew point, and wind speed significantly negatively correlated with COVID-19 cases, while precipitation was not significantly correlated with COVID-19 cases. However, only dew point at lag 0, lag 2, lag 10, and lag 12, wind speed at lag 9, lag 10, lag 12, lag 13, and lag 14 had a significant effect on the daily new COVID-19 cases. **Discussion:** This study demonstrated the effect of meteorological factors on daily new confirmed cases in Selangor, Malaysia. The results showed consistency and contradictions with the previous studies conducted in Malaysia. **Conclusion:** The findings from this study provide new insight into the relationship and lag effects between meteorological factors and daily new COVID-19 cases in Selangor, Malaysia. The government may take meteorological factors into considerations when making policies and allocating resources.

*Keywords:* COVID-19, overdispersion, zero-inflation, negative binomial, meteorological

© COPYRIGHT UPM

# ABSTRAK

## Kajian Faktor Meteorologi Berkaitan dengan Kes COVID-19 di Selangor, Malaysia

***Tan Yi Huan[a], Cheah Yoke Kqueen[a], Eliani Ezani[b], Anita Abd Rahman[c], Hasni Idayu Saidi[a]***

*[a]Jabatan Sains Bioperubatan, Fakulti Perubatan dan Sains Kesihatan, Universiti Putra Malaysia*

*[b]Jabatan Kesihatan Persekitaran dan Pekerjaan, Fakulti Perubatan dan Sains Kesihatan, Universiti Putra Malaysia*

*[c]Jabatan Kesihatan Komuniti, Fakulti Perubatan dan Sains Kesihatan, Universiti Putra Malaysia*

**Pengenalan:** Banyak kajian telah mengkaji hubungan antara faktor meteorologi dengan jangkitan COVID-19. Iklim di lokasi yang berbeza mempunyai kesan yang berbeza terhadap kes COVID-19. Oleh itu, kajian tentang faktor meteorologi dan kes COVID-19 mesti dijalankan secara khusus di satu lokasi sahaja. Penyelidik tempatan di Malaysia telah mengkaji hubungan antara faktor meteorologi dan kes COVID-19 di Kuala Lumpur dan Malaysia secara keseluruhan. Kajian sebegini juga mesti dijalankan di negeri yang mempunyai paling ramai penduduk di Malaysia, iaitu Selangor. **Objektif:** Kajian ini bertujuan untuk mengkaji hubungan antara faktor meteorologi dan kes COVID-19 di Selangor, Malaysia. Titik embun, suhu, kelembapan relatif, kerpasan, dan kelajuan angin adalah faktor meteorologi yang dikaji dalam kajian ini. **Metodologi:** Analisis korelasi pangkat Kendall dan analisis korelasi silang digunakan untuk mengawal kesan kolineariti dan ketinggalan. Model binomial negatif (NB) dan model binomial negatif sifar-melambung (ZINB) telah digunakan untuk menganggarkan kesan faktor meteorologi ke atas kes COVID-19. Semua faktor meteorologi penting akan dimasukkan dalam model. Model terbaik dipilih berdasarkan kriteria maklumat Akaike (AIC). Pemilihan ke belakang kemudiannya dilakukan dalam model pelbagai pembolehubah terpilih untuk memilih faktor meteorologi yang paling ketara dan mengoptimumkan model itu. **Keputusan:** ZINB adalah model terbaik dengan nilai AIC terendah. Suhu, kelembapan relatif, takat embun dan kelajuan angin berkorelasi secara negatif dengan kes COVID-19, manakala hujan tidak dikaitkan dengan kes COVID-19. Walau bagaimanapun, hanya titik embun pada lag 0, lag 2, lag 10 dan lag 12, kelajuan angin pada lag 9, lag 10, lag 12, lag 13 dan lag 14 mempunyai kesan yang ketara ke atas kes COVID-19. **Perbincangan:** Kajian ini menunjukkan kesan faktor meteorologi ke atas kes COVID-19 di Selangor, Malaysia. Keputusan kajian ini terdapat konsistensi dan juga percanggahan dengan kajian lepas di Malaysia. **Kesimpulan:** Hasil kajian ini memberikan pandangan baharu tentang hubungan dan kesan ketinggalan antara faktor meteorologi dan kes COVID-19 di Selangor, Malaysia. Kerajaan dicadangkan untuk mengambil kira faktor meteorologi apabila membuat dasar dan memperuntukkan sumber.

*Kata kunci:* COVID-19, binomial negatif sifar-melambung, binomial negatif, meteorologi

© COPYRIGHT UPM

**ACKNOWLEDGEMENT**

This project would not have been possible without the support of many people.

First and foremost, I would like to express my gratitude to my supervisor, Prof. Dr. Cheah Yoke Kqueen, and the co-supervisors, Dr. Eliani Ezani, Dr. Anita Abd Rahman, and Dr. Hasni Idayu Saidi for their invaluable advice and continuous support throughout the implementation of this project. I am grateful for all the freedom and space I have been given to work on this project where I learnt to be independent and accountable for my work.

My appreciation also goes out to my friends who supported me and offered deep insight into the research. I would like to specially thank Pang Zi Haur and Teea Yuan Xin for solving my programming and statistical problems.

Lastly, my gratitude extends to my family for their encouragement and unconditional support when I spent most of my time at home working on the project. Their trust in me has kept me motivated and confident throughout the process.

© COPYRIGHT UPM

## TABLE OF CONTENS



© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

# LIST OF TABLES



© COPYRIGHT UPM

# LIST OF FIGURES





© COPYRIGHT UPM

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ACE2 | Angiotensin-converting enzyme 2 |
| AIC | Akaike Information Criterion |
| CDC | Centers for Disease Control and Prevention |
| COVID-19 | Coronavirus Disease 2019 |
| DEWP | Dew point |
| DNCC | Daily new COVID-19 cases |
| ICC | Intraclass correlation coefficient |
| LRT | Likelihood ratio test |
| MCO | Movement control order |
| MERS-CoV | Middle East respiratory syndrome coronavirus |
| NB | Negative binomial |
| NCEI | National Centers for Environmental Information |
| NOAA | National Oceanic and Atmospheric Administration |
| PRCP | Precipitation |
| RH | Relative humidity |
| SARS-CoV | Severe acute respiratory syndrome coronavirus |
| SARS-CoV-2 | Severe acute respiratory syndrome coronavirus 2 |
| SOP | Standard Operating Procedure |
| TEMP | Temperature |
| VIF | Variance Inflation Factor |
| WDSP | Wind speed |
| WHO | World Health Organization |
| ZINB | Zero-inflated negative binomial |

© COPYRIGHT UPM

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The Coronavirus Disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) (World Health Organization, 2020b). SARS-CoV-2 is a β-coronavirus that causes severe respiratory infections like SARS-CoV and MERS-CoV that have also previously caused global outbreaks (Guo et al., 2020).

COVID-19 began spreading outside China, starting with the first imported case reported in Thailand. COVID-19 spread rapidly worldwide, soon surpassing 10 million confirmed cases in the United States and India by the end of 2020 (World Health Organization, 2020d). As of 24th April 2022, there were more than 500 million confirmed cases, and more than 6 million deaths were reported worldwide (World Health Organization, 2022c).

COVID-19 infections spread through various common pathway, including contact, droplet, airborne, and fomite (World Health Organization, 2020c). Contact and droplet transmission occurs when the viral-laden droplets exhaled by an infected individual enters the body of a susceptible individual in close contact through the openings of the eyes, nose, and mouth. World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) declared the airborne transmission of



© COPYRIGHT UPM

COVID-19, where smaller and lighter viral-laden droplets can travel through the air, carrying the virus further afield. Transmission of COVID-19 may also occur via indirect contact with surfaces contaminated with the virus, followed by the eyes, nose, and mouth (World Health Organization, 2020c). Therefore, social distancing, the use of face mask and face shield, and frequent hand washing are paramount in the prevention of COVID-19 infection (World Health Organization, 2022a)

## 1.2 Problem Statement

Since the COVID-19 outbreak, many researchers have been interested in understanding the relationship between meteorological factors and COVID-19. Extensive studies have been conducted around the world, including in China (Xie & Zhu, 2020), Brazil (Auler et al., 2020; Prata et al., 2020), Turkey (Şahin, 2020; Selcuk et al., 2021), Iran (Ahmadi et al., 2020), Singapore (Pani et al., 2020). Local researchers have also conducted several studies to analyse the effect of meteorological factors on COVID-19 cases in Kuala Lumpur, and all over Malaysia (Lloyd & Viswanathan, 2022; Makama & Lim, 2021; Suhaimi et al., 2020; M. L. Tan et al., 2021).

However, no consistent conclusions can be drawn to determine the relationship between meteorological factors and COVID-19 disease due to contradictions between studies from different countries. Malaysia's tropical climate, with its high temperature, humidity and rainfall almost all year round and little seasonal variation, may cause different effect on COVID-19 transmission compared to other countries with different climatic patterns (Makama & Lim, 2021).

© COPYRIGHT UPM

Furthermore, looking into the population density of each state of Malaysia, Selangor has the largest population size among the 13 states and three federal territories (Department of Statistics Malaysia, 2021). Therefore, it is essential to establish a location-specific study to investigate the relationship between the meteorological factors and COVID-19 cases in Selangor (Şahin, 2020).

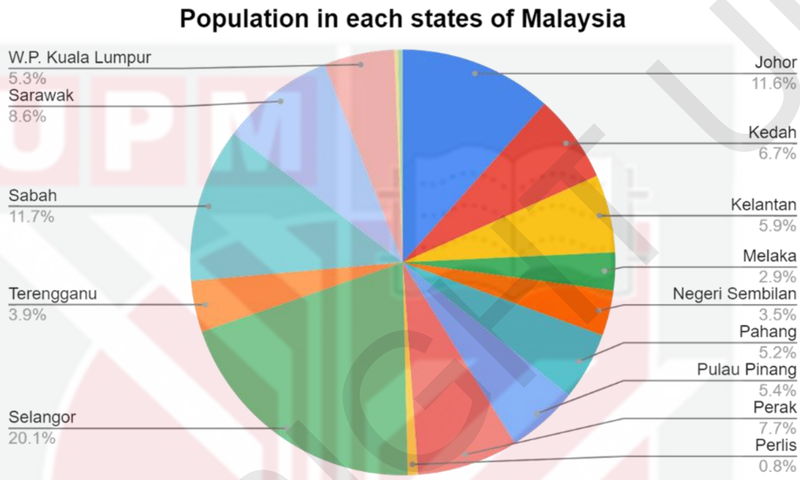


**Figure 1. Population distribution across each state of Malaysia in 2021. Selangor accounts for the largest proportion of Malaysia's population at 20.1%.**

In addition, as COVID-19 has an incubation period of 2 to 14 days, this study also aims to understand the lag effect of meteorological factors on COVID-19 cases in Selangor, with a lag time of up to 14 days (Chen et al., 2020; National Center for Immunization and Respiratory Diseases (NCIRD), 2022). To our knowledge, studies on the lag effect of meteorological factors and COVID-19 cases in Malaysia have not yet been established. Hence, this current study may be prominent to give new insight into the lag effect.

## 1.3 Objective

### 1.3.1 General Objective

This study aims to study the effect of the meteorological factors on the daily new COVID-19 cases in Selangor, Malaysia.

### 1.3.2 Specific Objective

1. To determine the relationship of the meteorological factors (temperature, relative humidity, dew point, relative humidity, precipitation) on daily new COVID-19 cases in Selangor, Malaysia.
2. To determine the lag effect of the meteorological factors (temperature, relative humidity, dew point, relative humidity, precipitation) on the daily new COVID-19 cases in Selangor, Malaysia.
3. To estimate the expected number of new daily COVID-19 cases based on meteorological factors (temperature, relative humidity, dew point, relative humidity, precipitation).

## 1.4 Hypothesis

1. Temperature, relative humidity, and wind speed are significantly negatively correlated with the daily new COVID-19 cases in Selangor, Malaysia.
2. Dew point is significantly positively correlated with the daily new COVID-19 cases in Selangor, Malaysia.



© COPYRIGHT UPM

3. Precipitation is not significantly correlated with the daily new COVID-19 cases in Selangor, Malaysia.
4. A one-unit increase in temperature, relative humidity, and wind speed with a lag of up to 14 days will decrease the number of daily new COVID-19 cases.
5. A one-unit increase in dew point with a lag of up to 14 days will increase the number of daily new COVID-19 cases.
6. A one-unit increase in precipitation with a lag up of to 14 days will neither increase nor decrease the number of daily new COVID-19 cases.

© COPYRIGHT UPM

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview of COVID-19

### 2.1.1 Origin of SARS-CoV-2

In December 2019, the Country Office of the World Health Organisation (WHO) in the People's Republic of China was alerted by the reported cluster of atypical pneumonia cases in Wuhan, Hubei Province, China (Hashim et al., 2021). It was then confirmed that the pneumonia is caused by a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The disease caused by SARS-CoV-2 is termed as Coronavirus Disease 2019 (COVID-19) (World Health Organization, 2020b). The outbreak of SARS-CoV-2 originated as zoonotic transmission via bat; however, it was later confirmed for human-to-human transmission (Kuo, 2020; World Health Organization (WHO) Western Pacific, 2020). Finally, realising the widespread of COVID-19 in 114 countries with a total of 118,000 confirmed cases and 4,291 death, on 11$^{th}$ March 2020, WHO declared COVID-19 as a global pandemic (World Health Organization, 2020e).

### 2.1.2 Background of SARS-CoV-2

There are four genera of coronaviruses (CoV), i.e. α−/β−/γ−/δ-CoV. SARS-CoV-2 is a β-coronavirus. β-coronavirus tends to infect mammals and cause severe respiratory



© COPYRIGHT UPM

tract infections. In the history of pandemic, there are two well-known β-coronavirus, SARS-CoV and MERS-CoV (Guo et al., 2020). These β-coronavirus share some similarities. SARS-CoV-2 shares 79% genome sequence identity with SARS-CoV and 50% with MERS-CoV (B. Hu et al., 2020; Jackson et al., 2021). In addition, SARS-CoV-2 and SARS-CoV use angiotensin-converting enzyme 2 (ACE2) as the functional receptor (Guo et al., 2020; Jackson et al., 2021). With all the similarities, SARS-CoV was widely used to study the COVID-19 pandemic, especially for treatment (Chen et al., 2020; Corman et al., 2020).

## 2.2 Epidemiology of COVID-19

### 2.2.1 Global Spread of COVID-19

Due to the travel rush during Chinese New Year period, the virus spread to other Chinese provinces and cities rapidly. Thailand is the first country outside China to report the first confirmed cases. This marked the beginning of the spread of COVID-19 worldwide. The case was imported by a Wuhan citizen travelling to Thailand on 8$^{th}$ January 2020 and reported positive on 13$^{th}$ January 2020. The disease continues to spread to other countries around the globe (Chowdhury & Oommen, 2020). Eventually, on 21$^{st}$ December 2020, Antarctica, which had remained coronavirus-free for almost a year, reported the first confirmed case as well.

The United States and India became the first two countries with at least ten million confirmed cases in late 2020. Brazil, the United Kingdom, and Russia joined the list in 2021. They are followed by France, Turkey, Italy, Germany, Spain, South Korea,



© COPYRIGHT UPM

Japan, and Vietnam to reach ten million confirmed cases in 2022 (World Health Organization, 2020d).

Globally, the number of new COVID-19 cases and deaths has continued to decline since the end of March 2022. As of 24th April 2022, over 500 million confirmed cases and over six million deaths had been reported globally (World Health Organization, 2022c).

### 2.2.2 COVID-19 Outbreak in Malaysia

As of 17th April 2022, a total of 4,389,025 confirmed cases and 35,421 deaths from COVID-19 had been reported in Malaysia. The overall case fatality rate is 0.8% (World Health Organization, 2022b).

The first three COVID-19 cases in Malaysia were reported on 25th January 2020, leading to the beginning of the first wave of COVID-19 in Malaysia. The three cases were recognised as imported cases by three Chinese citizens who were in close contact with a COVID-19 patient in Singapore (New Straits Times, 2020). The first wave of COVID-19 lasted approximately one month, ending on 16th February 2020. Along the first wave of COVID-19, a total of 22 cases were reported in Malaysia, with a 100% recovery rate for all the 22 cases. Afterwards, no case was reported for the 11 days after first wave of COVID-19 ended (Abdullah, 2020a).

The second wave of COVID-19 arose in Malaysia on 27th February 2020. The most significant cluster in the second wave of COVID-19 was a religious 4-day mass



© COPYRIGHT UPM

gathering at Sri Petaling, Selangor, with over 16,000 participants. It has contributed to a total of 3,375 positive cases (8.03%) over 42,023 tested samples in the second wave of COVID-19 and 17 subclusters with 1,353 positive cases. After no new case reported for 28 consecutive days since 11$^{th}$ June 2020, the Sri Petaling cluster was announced to end on 7$^{th}$ July 2020. (Abdullah, 2020b; Edinur & Safuan, 2020). The first and second wave of COVID-19 was not considered epidemiologically linked due to the 11-day gap of zero cases. It was also evidenced by the origin of the case, where the first wave originated from the Singapore imported case. In contrast, the second wave originated from local mass gatherings (Ghazali et al., 2022).

The third wave of COVID-19 in Malaysia was announced on 20$^{th}$ September 2020 as due to the Sabah state election (Haji Mohd Yassin, 2021; Ministry of Health of Malaysia, 2020b). The number of cases in Sabah worsened by the Sabah state election on 26$^{th}$ September 2020 (Hashim et al., 2021). Border control relaxation and election campaigns had exacerbated the surge in Sabah and other states throughout Malaysia, where there was high mobility for inter-state travelling during the campaign and voting period. Furthermore, loose Standard Operating Procedure (SOP) implementation might be one of the leading causes of the surge in which no COVID-19 test and 24-day quarantine were imposed on the returnees (Zainudin et al., 2020). Another significant cluster in the third wave of COVID-19 is the Teratai cluster which was declared on 7$^{th}$ November 2020 (Ministry of Health of Malaysia, 2020a). Teratai cluster originated from staff dormitories of Top Glove Corp Bhd in Meru, Klang. (Daud & Syed Jamaludin, 2021) had identified Teratai cluster as one of the top clusters with a high number of total cases among the existing clusters. Indeed, to date, the Teratai cluster that was announced ending on 17$^{th}$ April 2021 remained the



© COPYRIGHT UPM

biggest cluster since the COVID-19 outbreak in Malaysia, with 7,205 positive cases over 10,426 tested samples (KKMalaysia, 2021).

The number of daily new cases started to decline in early March 2021. Hence, movement control order (MCO) restrictions were lifted (Anand, 2021). However, the restrictions were reintroduced due to the resurgence of COVID-19 (Jayaraj et al., 2021). Malaysia is not considered to be experiencing the fourth wave of COVID-19 as long as the number of cases in the ongoing third wave was not lowered to the baseline or even recorded zero case before the COVID-19 cases surge again (Bernama, 2020). Due to the continued rise of COVID-19 cases, a total lockdown was implemented from 1st June to 14th June 2021 (Pejabat Perdana Menteri, 2021).

The Delta variant remained dominant in August 2021 (World Health Organization, 2021). However, on 3rd December 2021, the first Omicron case emerged in Malaysia. The number of new cases continued to surge due to the new Omicron variant, resulting in the new record number of new cases on 5th March 2022, with a total of 33,406 new cases. However, compared with the Delta wave from June 2021 to October 2021, Omicron brought a relatively minor impact in terms of health as it has lighter symptoms despite of high contagiousness. Furthermore, the rate of hospitalisation death in the Omicron wave was 80%-90% lower than in the delta wave period (Abdullah, 2022). Hence, at a press conference on 8th March 2022, the Prime Minister of Malaysia, Ismail Sabri Yaakob, announced that Malaysia would be moving into the Endemic phase starting from 1 April 2022 (Yaakob, 2022).

© COPYRIGHT UPM

### 2.2.3 COVID-19 Transmission

On 9th July 2020, WHO had published a scientific brief to confirm that SARS-CoV-2 is able to transmit via contact, droplet, airborne, fomite, faecal-oral, bloodborne, mother-to-child, and animal-to-human transmission (World Health Organization, 2020c). Furthermore, CDC also published another scientific brief to provide evidence to confirm the SARS-CoV-2 transmission pathway via airborne, close contact, and indirect contact (National Center for Immunization and Respiratory Diseases (NCIRD), 2021).

#### 2.2.3.1 Contact and Droplet Transmission

Large droplets (> 5 μm) can be deposited quickly near the emission point. Hence, droplet transmission occurs when a person comes into close contact (< 1 m) with an infected person who is sneezing, coughing, talking or exhaling, and the droplets contaminated with the virus deposited directly on the person (Morawska & Cao, 2020). The viral-laden droplet most often enters the body through the openings of the eyes, nose, and mouth (World Health Organization, 2020c). The virus transmission can occur with symptomatic and asymptomatic infected persons, however, people tend to take their guard down when in close contact with the latter. (Rothe et al., 2020). Therefore, social distancing and using face masks and face shield are recommended as precautions (World Health Organization, 2022a).

© COPYRIGHT UPM

#### 2.2.3.2 Airborne transmission

Airborne transmission of SARS-CoV-2 was confirmed by WHO and CDC (National Center for Immunization and Respiratory Diseases (NCIRD), 2021; World Health Organization, 2020c). Small droplets (< 5 µm) are formed when the exhaled droplets evaporate and become smaller. Since the droplets are just small and light, they can linger in the air for a longer time and travel up to tens of meters. These droplets might be inhaled by a susceptible person and eventually causes airborne infection (Morawska & Cao, 2020).

#### 2.2.3.3 Fomite Transmission

Deposition of viral-laden droplets creates a contaminated surface known as a fomite. Fomite transmission occurs indirectly when a susceptible person touches the virus-contaminated surface, followed by the eyes, nose, and mouth. A few factors influence the stability and survival of the virus on the fomite, including the types of surfaces in which either porous or non-porous surfaces, and ambient environment such as temperature and humidity (World Health Organization, 2020c). Therefore, we must wash our hands frequently (World Health Organization, 2022a).

#### 2.2.3.4 Other Modes of Transmission

A few studies that have collected rectal or anal swabs for virus detection suggest a positive result and faecal transmission as a potential transmission route (Pan et al., 2020; Wang et al., 2020). Sun et al. (2020) also isolated SARS-CoV-2 from urine

© COPYRIGHT UPM

samples and the samples were tested positive, suggesting the possibility of urine transmission. However, there have been no published reports of transmission of SARS-CoV-2 through faeces or urine (World Health Organization, 2020c).

Some studies have also reported the detection of SARS-CoV-2 RNA in blood and claimed that the virus could replicate in blood cells (Wang et al., 2020; Zhang et al., 2020). Bloodborne transmission is critical, especially in blood donation. We must avoid the tragedy in China where the donated blood was detected positive for SARS-CoV-2 RNA (Chang et al., 2020).

On 23rd June 2020, WHO published a scientific brief to suggest the SARS-CoV-2 transmission via breastfeeding. Several studies also reported the detection of SARS-CoV-2 RNA in breastmilk, indicating the possibility of viral transmission via breastfeeding (Groß et al., 2020; Tam et al., 2021). The brief also notes that breastfeeding is more important than infection since COVID-19 infection is only mild and asymptomatic in infants. However, the transmission route remains unclear whether the virus is transmitted through breastmilk or droplet from close contact with the infected mother (World Health Organization, 2020a).

It was suggested that bat is the natural host of SARS-CoV-2, but the intermediate host still remains unclear. Pangolin is a highly suspected candidate as an intermediate host to SARS-CoV-2. Several studies also revealed the possibilities of human-animal transmissions, such as farmed mink, cats, dogs, tigers, and lions, and confirmed the resistance of livestock such as chicken, pig, duck to the virus. (Mahdy et al., 2020; Zhao et al., 2020).

© COPYRIGHT UPM

## 2.3 Meteorological Factors Associated with COVID-19 Infection

### 2.3.1 Temperature

Temperature is the most frequently investigated meteorological factor in the COVID-19 study. High temperature evaporates the droplet faster and thus reduces the respiratory droplet transmission of the virus (Tang, 2009). In addition, coronavirus cannot stand high temperatures, and it will die off rapidly (Chan et al., 2011). Under high temperatures, the viral proteins and genome will be jeopardised (Tang, 2009). This is consistent with the cessation of the SARS outbreak in July 2003 when temperatures rose, and the weather became warmer (Tan et al., 2005). In addition, Chen et al. (2021) suggested that countries with hotter climate have fewer COVID-19 cases. Therefore, tropical countries with perennial high temperatures are claimed to be not conducive to the long-term survival of coronavirus. However, the outbreaks of SARS-CoV in Hong Kong and Singapore were relatively more severe than in Malaysia, Indonesia, and Thailand. This may be due to the widespread use of air-conditioning to lower the temperature in Hong Kong and Singapore. This case agrees with the claim that coronaviruses remain infectious at lower temperatures and continue to promote their transmission, increasing the incidence of reported cases (Chan et al., 2011). Several studies of COVID-19 in different countries such as Indonesia (Rendana, 2020), Turkey (Şahin, 2020; Selcuk et al., 2021), and Malaysia (Lloyd & Viswanathan, 2022; Suhaimi et al., 2020) also reflect consistent results. However, it is also important to note that some studies have shown contradictions with the above findings in which higher temperature increases COVID-19 case



© COPYRIGHT UPM

(Auler et al., 2020; Bashir et al., 2020; Makama & Lim, 2021; Pani et al., 2020; Tosepu et al., 2020; Xie & Zhu, 2020).

### 2.3.2 Relative Humidity

The relative humidity is the percentage of the water vapour content in the air at a particular temperature compared to the maximally saturated water vapour content in the air at the same temperature (Tang, 2009). There is a positive monotonic relationship between temperature and relative humidity in which the higher the temperature, the higher the relative humidity. The air at a higher temperature contains more water vapour, and so the air can hold more water vapour (Dotson, 2018).

Relative humidity affects the transmission of droplet-mediated viral diseases in terms of evaporation kinematics and virus infectivity (Ahlawat et al., 2020). In terms of evaporation kinematics, low relative humidity causes rapid droplet evaporation, leading to a smaller aerosol formation. The smaller-sized aerosol with a lower mass may suspend in the air for a longer time for subsequent infection (Cai et al., 2007; Morawska & Cao, 2020). On the contrary, when the water vapour holds a higher water vapour content at higher temperature, a large droplet will be formed and deposited quickly near the emission point (Feng et al., 2020; Lowen et al., 2007).

In terms of virus infectivity, low relative humidity may increase the infectivity of SARS-CoV-2. When inhaling air with low water vapour content, the dry air fails to moisturise the nose and throat. Dryness in the nose and throat may cause mucus to

© COPYRIGHT UPM

dry up and become viscous. In this case, the cilia in the nose and throat cannot expel the viral aerosols effectively. In addition, dry air with low humidity significantly disrupts the proper function of respiratory immunity. Breathing dry air may cause epithelial damage and thus increase the susceptibility to the virus (Ahlawat et al., 2020; Lowen et al., 2007).

In lines with the mechanism described above, previous studies also demonstrated that dry environment with low relative humidity (20% to 30%) is more survivable for coronaviruses (Ahlawat et al., 2020; Lin & Marr, 2020; Lowen et al., 2007; Tang, 2009).

### 2.3.3 Dew Point

Dew point refers to the temperature that causes 100% relative humidity. The air is fully saturated with water vapour content at the dew point. Dew point is the confounder that influence the relationship between temperature and COVID-19 by reducing high temperatures to low levels (Sarkodie & Owusu, 2020). As discussed in the previous section, low temperature is conducive for virus survival. Hence, dew point plays a role in promoting virus transmission.

However, the relationship of dew point itself with COVID-19 infection has contradicting findings. Several studies suggest a negative effect of dew point on COVID-19 (Şahin, 2020; Selcuk et al., 2021), while some claim a positive effect (Lloyd & Viswanathan, 2022; Pani et al., 2020; Sarkodie & Owusu, 2020). These inconsistent results deserve further investigation in the present study.



© COPYRIGHT UPM

### 2.3.4 Precipitation

Water vapour in the air naturally evaporates and condenses when the air reaches 100% relative humidity. When it condenses to a certain extent and limits, it is pulled by gravity and falls back to the earth. This falling, highly condensed product is known as precipitation. In Malaysia, precipitation is usually referred as rainfall.

Although the relationship between precipitation and the COVID-19 case has been extensively studied, scarce studies have explained how precipitation affects the spread of COVID-19. However, it is suggested that precipitation increases the transmission of the virus. This is due to the high relative humidity associated with precipitation and may therefore prolong the virus survival and increase the transmission of the virus (Lloyd & Viswanathan, 2022; Sarkodie & Owusu, 2020; Sobral et al., 2020; Wei et al., 2020). Precipitation is also a confounding factor in the COVID-19-temperature relationship, which it lowers down high temperatures and facilitates virus transmission (Sarkodie & Owusu, 2020). On the other hand, precipitation may reduce human activities and wash away the virus lingering in the air, resulting in a lower risk of virus transmission (Chowdhury et al., 2018; Menebo, 2020). In any case, numerous studies have shown that precipitation is not significantly associated with the spread of COVID-19 (Auler et al., 2020; Bashir et al., 2020; Rendana, 2020; Tan et al., 2021; Tosepu et al., 2020).

© COPYRIGHT UPM

### 2.3.5 Wind Speed

Droplet-mediated viral diseases may be influenced by wind speed as wind transports the viral-laden droplets to various destinations (Sarkodie & Owusu, 2020). In addition, high wind speed tends to decrease the viral concentration in the droplets and shorten the suspending time of the droplets in the air, resulting in a lower risk of coronaviruses transmission. (Cai et al., 2007). This is in line with several studies in Malaysia (Daud & Syed Jamaludin, 2021; Lloyd & Viswanathan, 2022; Makama & Lim, 2021; Tan et al., 2021), Singapore (Pani et al., 2020), Indonesia (Rendana, 2020), Iran (Ahmadi et al., 2020), and Turkey (Şahin, 2020).

However, on the contrary, some studies demonstrated a positive effect of wind speed on COVID-19 cases (Wei et al., 2020; Yang et al., 2021; Zhou et al., 2022). This opposite result may be due to high wind speeds increasing the distance of transmission of SARS-CoV-2 and creating turbulence within the city (van Doremalen et al., 2020; Yang et al., 2021).



© COPYRIGHT UPM

**CHAPTER 3**

# METHODOLOGY

## 3.1 Study Area

The targeted area of this study is Selangor, Malaysia, which lies between latitude 3.0738°N and longitude 101.5183°E, covering approximately 8,104 km² of land areas. Selangor is the most populous state in Malaysia, with a population density of 6.56 million in 2021 (Department of Statistics Malaysia, 2021). Due to its dense population, Selangor is a pivotal location to study the spread of COVID-19 transmission regarding meteorological factors. Furthermore, Bashir et al. (2020) have stressed the significance of analysing meteorological variables in an area with a high population density.

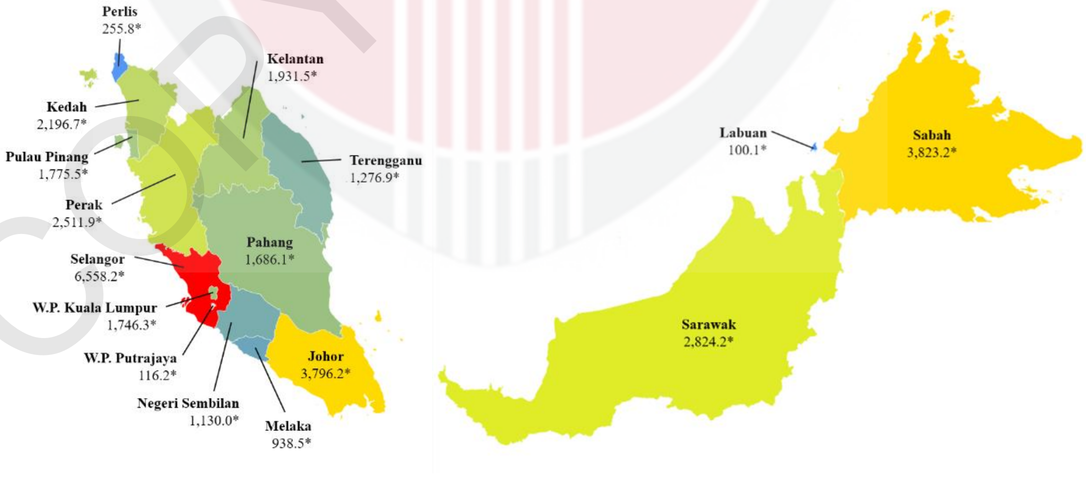


**Figure 2. Population density across states in Malaysia as of 8th November 2021. Asterisk (*) represents numbers in thousands. The population in Selangor is approximately 6,558,200.**
(Source: Department of Statistics Malaysia, 2021)

© COPYRIGHT UPM

## 3.2 Study Duration

The study analyzed the relationship between COVID-19 cases and meteorological factors from the first day of the COVID-19 outbreak in Malaysia until the current date, i.e. 22nd May 2022. On 25th January 2020, Malaysia reported the first three COVID-19 cases, marking the start of COVID-19 dissemination in Malaysia. Up to the time of this study (22nd May 2022), there has been a total of 4,491,320 confirmed cases reported in Malaysia, while Selangor contributed 30.26% (1,358,936) of the total cases.

## 3.3 Data Collection and Estimations

Secondary data of daily new COVID-19 cases in Selangor was obtained from the GitHub repository of the Ministry of Health (MoH), Malaysia (available at https://github.com/MoH-Malaysia/covid19-public).

Meteorological data from the two principal weather stations in Selangor, KLIA Sepang station (2.73°N, 101.70°E) and Subang station (3.13°N, 101.55°E), was retrieved from National Centers for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA). The dataset consists of daily records of dew point, mean temperature, precipitation, and wind speed. NCEI is deemed a reliable online resource for atmospheric research applications as many researchers have used the data from NCEI in their studies (Chen et al., 2020; Sobral et al., 2020; Zhou et al., 2022). In addition, extensive automated quality control (QC) was performed to eradicate random errors in the original input data. Further QC was



© COPYRIGHT UPM

also conducted again upon aggregating of the summary of day dataset. However, NCEI does not claim 100% accuracy of the dataset where a small percent of errors might still be expected (Lackey, 2020).


**Figure 3. Location of the KLIA Sepang and Subang weather stations in Selangor, Malaysia. These two weather stations measure and provide the data on temperature, dew point, precipitation, and wind speed in Selangor.**

Relative humidity was computed from temperature (TEMP) and dew point (DEWP) using the August-Roche-Magnus estimation as described in equation (1) (Alduchov & Eskridge, 1996; Fassò et al., 2022; Tang, 2009).

$$RH\ [\%] = 100 \times e^{\frac{17.625 \times DEWP}{243.04 + DEWP} - \frac{17.625 \times TEMP}{243.04 + TEMP}} \quad (1)$$

## 3.4 Data Preparation

Both datasets of COVID-19 cases and meteorological factors were assessed for any missing data. The missing data were replaced by the mean (Nor et al., 2020).

The initial units of the dew point and temperature (°F), precipitation (inches), and wind speed (knot) were converted to SI units, i.e. degree Celsius (℃), millimeters (mm), meters per second (m/s) using the following formulas, respectively (Butcher et al., 2006; Thompson & Taylor, 2008)

$$TEMP\ [℃] = (TEMP\ [°F] - 32) \times 1.8 \quad (2)$$

$$PRCP\ [mm] = PRCP\ [inches] \times 25.4 \quad (3)$$

$$WDSP\ [m/s] = WDSP\ [knot] \times 0.5144 \quad (4)$$

where TEMP represents both dew point and temperature, PRCP represents precipitation, and WDSP represents wind speed.

Since this study looks into the relationship between meteorological factors and COVID-19 in Selangor state, the meteorological data from KLIA Sepang and Subang stations were aggregated to represent Selangor data by simple average (Hong et al., 2015).

© COPYRIGHT UPM

Finally, each meteorological factor was duplicated with 1 to 14 days lags. Lagged meteorological factors are essential in the following analysis examining the lag effects of meteorological variables on COVID-19 cases (He et al., 2021; Hu et al., 2021).

All the data preparation was performed using RapidMiner software with version 9.10.

## 3.5 Data Analysis

### 3.5.1 Descriptive Analysis

Descriptive analysis was performed to provide the basic information of the dataset. The data for each variable was summarised into minimum value, median, maximum value, mean, and variance to understand the central tendency and the spread of the data (Anggreainy et al., 2022; Iqbal et al., 2022).

### 3.5.2 Kendall Rank Correlation

Since the dependent variable is not normally distributed, Kendall rank correlation test was deployed to evaluate the relationship between the meteorological factors and daily COVID-19 cases (Bashir et al., 2020; Pani et al., 2020). Kendall rank correlation coefficient, Kendall's tau ($\tau$), indicates the direction and strength of a monotonic relationship between two variables using the equation as follows

$$\tau = \frac{n_c - n_d}{n(n-1)/2} \tag{5}$$



© COPYRIGHT UPM

where $n_c$ and $n_d$ is the number of concordant and discordant pairs respectively, and $n$ is the number of pairs. The value of $\tau$ lies in the range of -1 to +1, and its strength was interpreted according to the guidelines proposed by Botsch (2011). Kendall rank correlation is crucial to identify the significant meteorological variables for the following modelling. Multicollinearity between meteorological variables was also identified through Kendall rank correlation. If multicollinearity is suspected, Variance Inflation Factor (VIF) was used to detect the strength of multicollinearity. The meteorological variables with a VIF greater than five should be eliminated one by one, starting with the highest VIF, until the rest has a VIF below five (Kim, 2019).

### 3.5.3 Cross-Correlation

In order to identify the lag effects of meteorological variables on COVID-19 cases, the meteorological variables selected from the previous correlation and multicollinearity tests were tested by cross-correlation for a maximum of 14 lags. Only meteorological variables with significant lags were included in the following modelling (Gao et al., 2016; Iqbal et al., 2022; C. Wang et al., 2014).

### 3.5.4 COVID-19 Time Series Diagnostic

Ljung-Box Q test was performed to determine if COVID-19 cases across the study period were random and independent (Hossain et al., 2021). If autocorrelation of COVID-19 cases presents, it was included in the modelling as an independent variable with a lag of one day (Gao et al., 2016; Iqbal et al., 2022; C. Wang et al., 2014).

© COPYRIGHT UPM

Long-term trend was observed in COVID-19 cases and validated using Mann-Kendall test. Mann-Kendall commonly detects the significance of a trend by analysing the correlation between COVID-19 and its time series (Chowdhuri et al., 2022; Goswami et al., 2020). No evident seasonality was observed in COVID-19 cases. The presence of seasonality was validated using Friedman's test based on the significance of the difference between period-specific mean (Chirumbolo et al., 2022; Fomby, 2010; Ollech, 2021).

### 3.5.5 Examine Overdispersion and Zero-Inflation

Poisson model is a popular method for modelling count data (Sellers & Shmueli, 2010). It was first proposed to model the relationship between COVID-19 cases and the meteorological factors in this study. However, in Table 1, the variance ($\sigma^2 = 5274911$) of COVID-19 cases is far greater than the mean ($\mu = 1600.63$), which leads to overdispersion. Zero-inflation was also suspected when the mode of COVID-19 cases is 0. In order to further validate the overdispersion and zero-inflation of COVID-19 cases, a Poisson regression model was used to fit COVID-19 cases and the statistically significant lagged meteorological variables. The overdispersion and zero-inflation were then examined using *overdisp* and *performance* packages in R (Cameron & Trivedi, 2020; Lüdecke et al., 2021). The overdispersion test developed in *overdisp* package is based on the study of Cameron and Trivedi (1990). The zero-inflation examination in *performance* package is based on comparing the amount of predicted and observed zeros. If the amount of observed zero is greater than predicted zero, zero inflation is confirmed.

© COPYRIGHT UPM

### 3.5.6 Model Selection

Due to overdispersion of the data, a negative binomial (NB) model was proposed (Iqbal et al., 2022; Jafarzadeh et al., 2014; Paulo Fávero et al., 2021). NB model is an extension of Poisson model with an addition of an overdispersion parameter (Iqbal et al., 2022). Hence, it was commonly used to model count data when the assumption of Poisson model, where variance equals mean, is violated (Iqbal et al., 2022; Paulo Fávero et al., 2021). COVID-19 cases and all the statistically significant lagged meteorological variables were modelled by NB model using *MASS* package in R (Venables & Ripley, 2002).

To compare the goodness of fit between Poisson and NB model, a likelihood ratio test (LRT) was performed (Iqbal et al., 2022). LRT tests the null hypothesis that the reduced or simpler model, i.e. the one with fewer parameters, fits the data equally well compared to the general or relatively complex model, whereas the alternative hypothesis that the complex model is fits the data better (White & Bennetts, 1996). NB model is considered a relatively more complex model than Poisson model due to the addition of the overdispersion parameter (Iqbal et al., 2022). Hence, LRT was expected to reject the null hypothesis and deploy the complex model, i.e. the NB model.

In addition to zero-inflation, a zero-inflated negative binomial (ZINB) model is also considered (Iqbal et al., 2022; Jafarzadeh et al., 2014; Paulo Fávero et al., 2021). *pscl* package in R was used to fit ZINB model with COVID-19 cases and all the statistically significant lagged meteorological variables (Zeileis et al., 2008).



© COPYRIGHT UPM

In order to select the model among NB and ZINB, Vuong test was performed to examine if the overdispersion of COVID-19 cases was caused by the excess zeros and determine which negative binomial model is more suitable for this study (Vuong, 1989). Vuong test is a likelihood-ratio-based test. It tests the null hypothesis that NB and ZINB models equally well fit the data against the alternative that ZINB model fit the data better than NB model.

### 3.5.7 Feature Selection

Backward elimination was performed to select the most important lagged meteorological factors and optimize the model (Iqbal et al., 2022; Wang et al., 2015). Backward selection begins with a set of statistically significant lagged meteorological variables determined from the previous cross-correlation. The least significant variable was eliminated stepwise until the ZINB model gives the lowest Akaike Information Criterion (AIC) value (Wang et al., 2015).

In order to assess if the reduced model is statistically better than the initial model, LRT was performed (Zeileis et al., 2008). In this case, LRT was expected to be insignificant in which the null hypothesis failed to be rejected, and the reduced model shall be chosen.

© COPYRIGHT UPM

### 3.5.8 Model Reliability

Finally, intraclass correlation was performed to evaluate the reliability of ZINB model by assessing the consistency between the actual and predicted data (Gao et al., 2016; Wang et al., 2014). The intraclass correlation coefficient (ICC) was calculated based on a single-measurement, absolute-agreement, two-way random-effects model

$$ICC = \frac{MS_R - MS_E}{MS_R + MS_E(k-1) + \frac{k}{n}(MS_C - MS_E)} \quad (6)$$

where $MS_R$ is the mean square for COVID-19 case count, $MS_E$ is the mean square for error, $MS_C$ is the mean square between the predicted and observed COVID-19 case count, $n$ is the number of observations, and $k$ is the number of measurements (Koo & Li, 2016; McGraw & Wong, 1996). ICC lies in the range of 0 to 1. The reliability was interpreted according to the guidelines proposed by Koo and Li (2016).

All the data analysis was performed using RStudio software with version 4.2.0.

© COPYRIGHT UPM

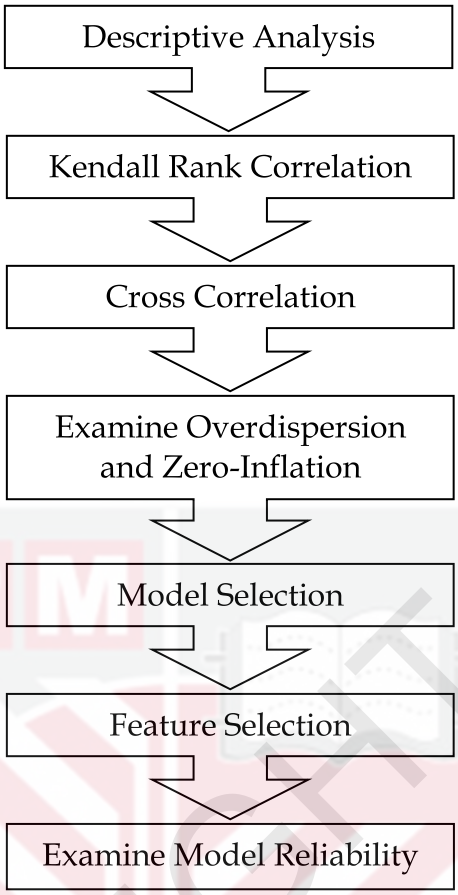


**Figure 4. Flowchart summarising the steps to analyse the relationship between the daily new COVID-19 cases and the meteorological factors in Selangor, Malaysia. Descriptive analysis was first performed to understand the features of the dataset. The relationship and multicollinearity between the variables were then examined using Kendall rank correlation. Cross-correlation was performed to identify the significant lags of the independent variables. Next, a Poisson model was used to confirm overdispersion and zero-inflation of the dependent variables. If overdispersion and zero-inflation are present, Vuong test shall be performed to select the best model among negative binomial and zero-inflated negative models. Once the best model was selected, backward elimination was applied in the selected model to select the most significant lagged independent variables for modelling. Lastly, the reliability of the model was examined.**

# CHAPTER 4

# RESULTS

## 4.1 Descriptive Analysis

Descriptive analysis results for all variables are presented in Table 4.1. At the beginning of the COVID-19 outbreak in Malaysia, Selangor recorded as low as 0 daily new cases. However, Selangor logged the highest number of daily new cases at 11,692 when COVID-19 continue to spread till 22$^{nd}$ May 2022.

Dew point is the temperature when the air is cooled to become saturated. Dew point ranged from 19.42 ℃ to 26.58 ℃ during the study period. Malaysia has a tropical climate, and the ambient air temperature was recorded as low as 23.47 ℃ and as high as 30.78 ℃ with a slight variation of 7.31 ℃. Relative humidity is the percentage of the water vapour content in the air compared to the maximal saturated water vapour content in the air at a particular temperature. The relative humidity varied from 54.76% to 96.08%, with an average of 78.50%. During the observation period, Selangor occasionally received a maximum of 160.53mm of rainfall, and the wind speed ranged from 0.67m/s to 3.58m/s.

© COPYRIGHT UPM

**Table 1. Descriptive statistical result of COVID-19 cases and the meteorological factors.**

| Variables | Min | Median | Max | Mean | Variance |
|---|---|---|---|---|---|
| **DNCC** | 0 | 751 | 11,692 | 1,601 | 5,230,828 |
| **DEWP (℃)** | 19.42 | 23.92 | 26.58 | 23.84 | 0.83 |
| **TEMP (℃)** | 23.47 | 28.00 | 30.78 | 27.99 | 1.18 |
| **RH (%)** | 54.76 | 78.54 | 96.08 | 78.50 | 35.15 |
| **PRCP (mm)** | 0.00 | 1.91 | 160.53 | 7.37 | 155.28 |
| **WDSP (m/s)** | 0.67 | 1.52 | 3.58 | 1.58 | 0.16 |

DNCC: daily new COVID-19 cases; DEWP: dew point; TEMP: temperature; RH: relative humidity; PRCP: precipitation; WDSP: wind speed

## 4.2 Kendall Rank Correlation Analysis

Table 2 shows the result of Kendall rank correlation test. The strength of the coefficients was interpreted using the guidelines provided in Table 3 (Botsch, 2011). The result showed that all the meteorological factors, except precipitation, are significantly correlated with COVID-19 cases. Hence, precipitation was not considered in the modelling of COVID-19 cases and meteorological factors. Dew point has a moderate negative correlation with COVID-19 cases at 0.01% significance level. Temperature, relative humidity, and wind speed are weakly and negatively correlated with COVID-19 cases at 5% significance level.

In addition, all the independent variables, i.e. meteorological factors, were significantly correlated with each other, suspecting multicollinearity. Therefore, the Variance Inflation Factor (VIF) was used to detect the severity of multicollinearity. Figure 5 clearly showed that VIF for relative humidity, temperature, and dew point was greater than 5, which is potentially concerning. However, after removing relative

© COPYRIGHT UPM

humidity that had the highest VIF, the VIF dropped below 5 (Figure 6). Therefore, relative humidity was eliminated in the following modelling of COVID-19 cases and meteorological factors.

**Table 2. The coefficients of pairwise Kendall rank correlation between COVID-19 cases and the meteorological factors.**

| | DNCC | DEWP | TEMP | RH | PRCP | WDSP |
|---|---|---|---|---|---|---|
| **DNCC** | 1 | | | | | |
| **DEWP** | -0.22*** | 1 | | | | |
| **TEMP** | -0.09* | 0.12*** | 1 | | | |
| **RH** | -0.07* | 0.34*** | -0.54*** | 1 | | |
| **PRCP** | -0.02 | 0.10** | -0.30*** | 0.34*** | 1 | |
| **WDSP** | -0.09* | -0.14*** | 0.23*** | -0.30*** | -0.13*** | 1 |

DNCC: daily new COVID-19 cases; DEWP: dew point; TEMP: temperature; RH: relative humidity; PRCP: precipitation; WDSP: wind speed
* p-value < 0.05
** p-value < 0.01
***p-value < 0.001

**Table 3. The interpretation guideline for Kendall rank correlation coefficient.**

| Strength | Kendall Tau B Coefficient |
|---|---|
| **Very weak** | Less than + or - 0.10 |
| **Weak** | + or -0.10 to 0.19 |
| **Moderate** | + or - 0.20 to 0.29 |
| **Strong** | + or - 0.30 or above |

© COPYRIGHT UPM

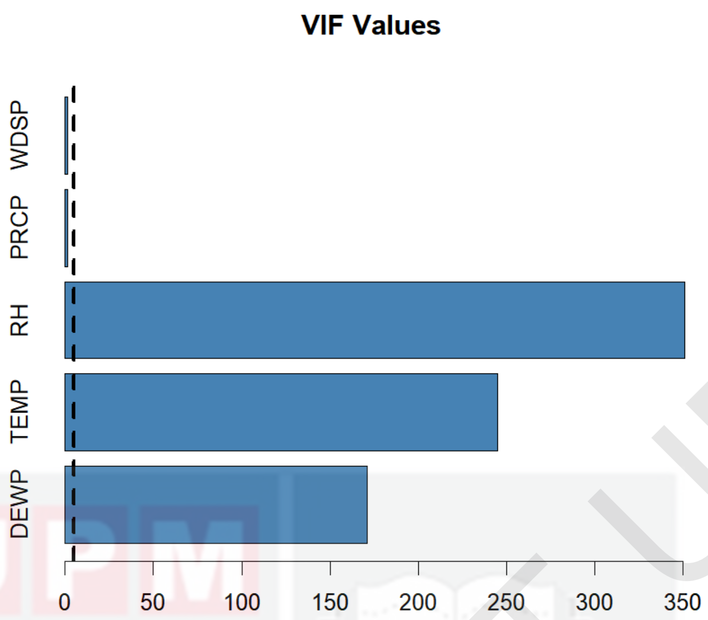


**Figure 5. VIF Values of the meteorological factors. The dotted vertical line indicates the threshold value. The VIF values of relative humidity (RH), temperature (TEMP), and dew point (DEWP) was greater than the threshold value, indicating potential multicollinearity among them.**

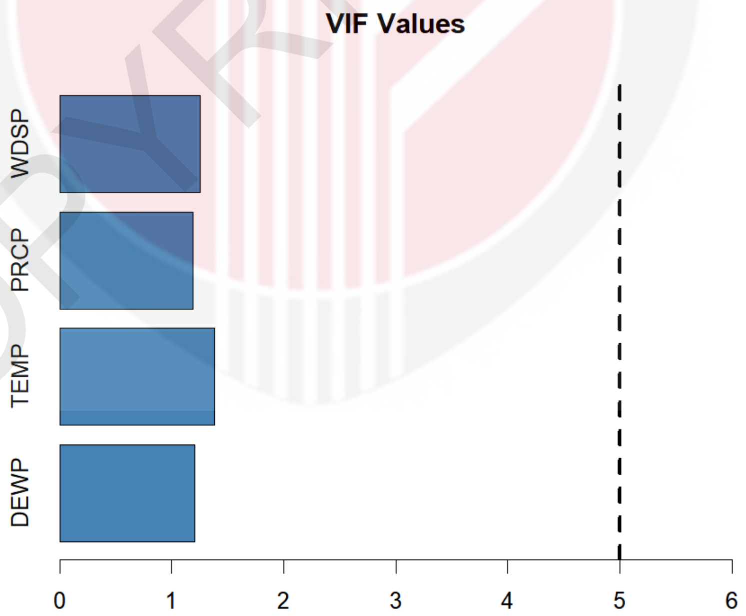


**Figure 6. VIF Values of the meteorological factors after the elimination of relative humidity. The dotted vertical line indicates the threshold value. The VIF values of wind speed (WDSP), precipitation (PRCP), temperature (TEMP), and dew point (DEWP) was below the threshold value.**

© COPYRIGHT UPM

## 4.3 Cross-Correlation

From the previous correlation and multicollinearity tests, only dew point, temperature, and wind speed were selected for the modelling of the relationship between meteorological factors and COVID-19 cases. In cross-correlation, a significant negative correlation was found between COVID-19 cases and dew point at lags of 0 to 14 days and wind speed at lags of 9 to 14 days. Temperature did not show a significant correlation with COVID-19 cases at any lags. All the statistically significant lagged variables were included in the following modelling.

**Table 4. Cross-correlation coefficients between daily new COVID-19 cases and meteorological variables with a lag of 0 to 13 days in Selangor, Malaysia.**

| Lag (days) | Dew Point | Temperature | Wind Speed |
|---|---|---|---|
| **0** | -0.167* | -0.036 | -0.043 |
| **1** | -0.168* | -0.036 | -0.055 |
| **2** | -0.170* | -0.043 | -0.061 |
| **3** | -0.161* | -0.043 | -0.064 |
| **4** | -0.158* | -0.029 | -0.065 |
| **5** | -0.165* | -0.031 | -0.066 |
| **6** | -0.171* | -0.038 | -0.064 |
| **7** | -0.172* | -0.047 | -0.066 |
| **8** | -0.186* | -0.043 | -0.065 |
| **9** | -0.178* | -0.061 | -0.081* |
| **10** | -0.171* | -0.067 | -0.098* |
| **11** | -0.176* | -0.059 | -0.087* |
| **12** | -0.181* | -0.049 | -0.083* |
| **13** | -0.184* | -0.050 | -0.084* |
| **14** | -0.190* | -0.052 | -0.084* |

*p-value < 0.05.



© COPYRIGHT UPM

## 4.4 COVID-19 Time Series Diagnostic

Ljung-Box Q test, Friedman test, and Mann-Kendall test were performed to assess the presence of autocorrelation, seasonal pattern, and trend pattern in COVID-19 case counts, respectively.

### 4.4.1 Ljung-Box Q Test

COVID-19 cases showed autocorrelation (p-value < 0.001). Hence, COVID-19 cases, though a dependent variable, was included in the model as an independent variable with a lag of one day (Gao et al., 2016; Iqbal et al., 2022; C. Wang et al., 2014).

### 4.4.2 Friedman Test

Friedman test with p-value of 0.12 > 0.05 fails to reject the null hypothesis that there is no difference between the period-specific mean, indicating that there is no seasonal pattern. Hence, seasonal factor was not required in the model.

### 4.4.3 Mann-Kendall Test

According to Mann-Kendall test, there is a significant trend (p-value < 0.001) present in the dependent variable, i.e. COVID-19 cases. Therefore, a time trend variable was introduced in the model to avoid spurious regression problem (Wooldridge, 2015). Time trend variable is a sequence of integers that represents the number of days of

© COPYRIGHT UPM

observation. The increasing trend of daily new COVID-19 cases was illustrated in Figure 7.

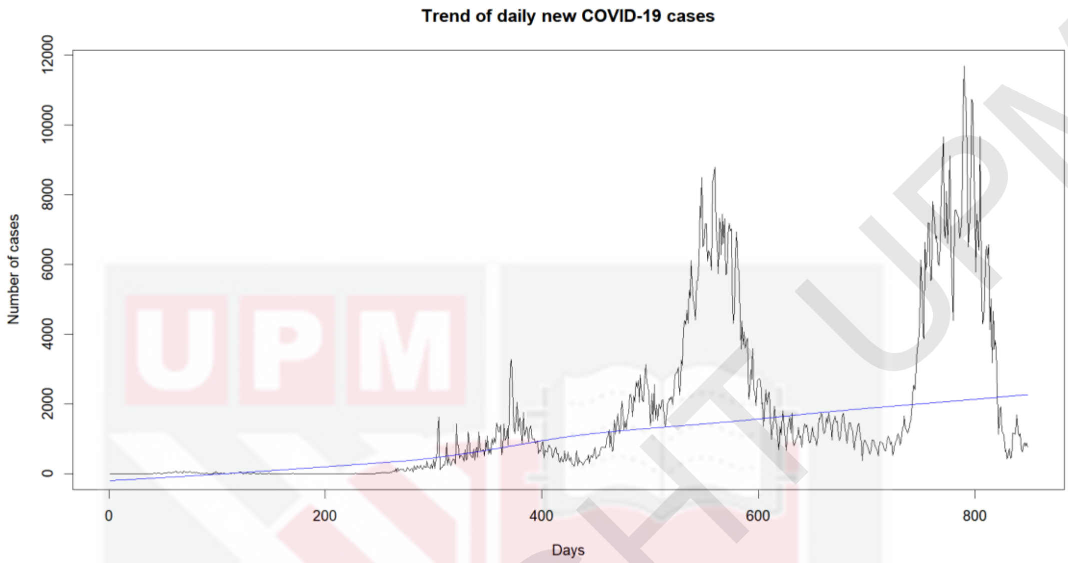


**Figure 7. A graph charting daily new COVID-19 cases in Selangor from 25th January 2020 to 22nd May 2022 (black line). COVID-19 cases, generally, showed an increasing trend across the observation period (blue line). The observation period was expressed as the number of days.**

## 4.5 Overdispersion and Zero-Inflation Examination

A Poisson regression model that modelled the relationship between COVID-19 cases and the meteorological factors was tested with overdispersion. The result (p-value < 0.001) rejected the null hypothesis that the dependent variable is equidispersed and validated the overdispersion of COVID-19 cases.

In zero-inflation test, the observed zero and predicted zero in the Poisson model is 40 and 0, respectively, suggesting that the model is underfitting zeros. Hence, this study recommends a negative binomial or zero-inflated model to model the relationship between COVID-19 cases and the meteorological factors in this study.



© COPYRIGHT UPM

### 4.6 Model Selection

Likelihood ratio test (LRT) was performed to validate if negative binomial (NB) model better fits the data than Poisson model. The p-value of the test is less than 0.001, confirming that NB model outperformed Poisson model.

Next, we assessed and validated the necessity to deploy a zero-inflated model using Vuong test. The test rejects the null hypothesis at 5% level of significance (p-value < 0.001), suggesting that the zero-inflated negative binomial (ZINB) model significantly provided better fit to the data than a standard NB model. Hence, a ZINB model was ultimately selected to model the relationship between COVID-19 cases and the meteorological factors.

### 4.7 Feature Selection

Backward elimination reduced the AIC value from 11855.22 to 11832.17. To validate if a reduced model is statistically better than the initial model, LRT was performed. The result fails to reject the null hypothesis that the nested and simpler model should be used (p-value = 0.21 > 0.05). Hence, the backward elimination was valid, and the reduced model was deployed to analyse the relationship between COVID-19 cases and the meteorological factors. The final model included the variables of daily new COVID-19 cases at a lag of 1 day, dew point at lags of 0, 2, 10, and 12 days, wind speed at lags of 9, 10, 12, 13, and 14 days, and time trend in the count model, while daily new COVID-19 cases at a lag of 1 day, dew point at



© COPYRIGHT UPM

lags of 3, 4, and 9 days, wind speed at lags of 10, and 11 days, and time trend in the zero-inflation model (Table 6).

## 4.8 Model Reliability

The reliability of the final model was examined using intraclass correlation. The intraclass correlation coefficient (ICC) was 0.592 (95% confidence interval [CI] = 0.53-0.64) with p-value smaller than 0.001, suggesting moderate reliability (Table 7) (Koo & Li, 2016).

**Table 5. The interpretation guideline for intraclass correlation coefficient (ICC).**

| Reliability | ICC |
|---|---|
| **Poor** | Less than 0.50 |
| **Moderate** | 0.50 to 0.75 |
| **Good** | 0.75 to 0.90 |
| **Excellent** | Greater than 0.90 |

## 4.9 ZINB Analysis

The output of the ZINB model presents two parts of the model, one for the count model, and one for the zero-inflation model. The count model is the focus as it tells the effect of the predictor variables at different lags on COVID-19 cases. On the other hand, the zero-inflation model tells the likelihood to have zero cases. The output presented in Table 4 is a reduced model where other insignificant meteorological variables were excluded in the model.



© COPYRIGHT UPM

The coefficient of dew point with a lag of 0, 2, 10, and 12, wind speed with a lag of 9, 10, 12, 13, and 14, and time trend in the count model predicting the COVID-19 cases is statistically significant. When other variables are held constant, the number of daily new COVID-19 cases decreases by 0.85 times for every one-degree-Celsius increase in dew point at lag 0 at lag 2, while the number of cases decreases by 0.82 times for every one-degree-Celsius increase in dew point at lag 10, and lag 12. In terms of wind speed, a one-unit increase in wind speed at lag 9, lag 10, lag 12, lag 13, and lag 14 decreases the number of daily new COVID-19 cases by 0.79, 0.63, 0.85, 0.75, and 0.73 times, respectively, when other variables are held constant. The count model also showed that increasing time trend was associated with increased daily new COVID-19 cases. For every one day increase in time, the number of daily new confirmed COVID-cases was expected to increase by 1.01 times.

It is important note the result of the number of daily new COVID-19 cases with a lag of 1 day is not a value (NaN). Hence, there is no reasonable estimate obtained for the number of daily new COVID-19 cases at lag 1 to predict the number of daily new COVID-19 cases effectively.

Meanwhile, the coefficient of daily new COVID-19 cases with a lag of 1 day, dew point with a lag of 3 and 4 days, wind speed with a lag of 9, 10, and 11 days in the zero-inflation model predicting the likelihood to achieve zero daily new COVID-19 cases are statistically significant. The odds of being an excessive zero would decrease by 0.53, 0.17, 0.28, and 0.15 for every one-unit increase in daily new cases at lag 1, dew point with a lag of 3, wind speed with a lag of 9, and 10, respectively. This implies that the likelihood that daily COVID-19 count would be zero in



© COPYRIGHT UPM

Selangor decreases with an increase in daily new cases at lag 1, dew point with a lag of 3, wind speed with a lag of 9, and 10.

On the other hand, greater dew point at lag 4, and wind speed at lag 11 exhibited an increase likelihood of zero cases. The odds of being an excessive zero would increase by 3.56 and 4.98 times for every one-unit increase in dew point at lag 4, and wind speed at lag 11, respectively.

© COPYRIGHT UPM

**Table 6. Results of the zero-inflated negative binomial model for daily new COVID-19 cases in Selangor, Malaysia from 25th January 2020 to 22nd May 2022.**

| | Coefficient | SE | Z | *p* | IRR |
|---|---|---|---|---|---|
| ***Count Model*** | | | | | |
| Constant | 23.35 | 1.22 | 19.08 | <0.01 | - |
| DNCC1 | 0.00 | NaN | NaN | NaN | 1.00 |
| DEWP | -0.16 | 0.06 | -2.64 | <0.01 | 0.85 |
| DEWP2 | -0.16 | 0.06 | -2.68 | <0.01 | 0.85 |
| DEWP10 | -0.19 | 0.06 | -3.32 | <0.01 | 0.82 |
| DEWP12 | -0.20 | 0.06 | -3.55 | <0.01 | 0.82 |
| WDSP9 | -0.23 | 0.09 | -2.44 | <0.05 | 0.79 |
| WDSP10 | -0.46 | 0.10 | -4.56 | <0.01 | 0.63 |
| WDSP12 | -0.39 | 0.10 | -3.87 | <0.01 | 0.68 |
| WDSP13 | -0.29 | 0.10 | -2.73 | <0.01 | 0.75 |
| WDSP14 | -0.31 | 0.10 | -3.18 | <0.01 | 0.73 |
| Time | 0.01 | 0.00 | 35.97 | <0.01 | 1.01 |
| Log(theta) | 0.08 | 0.04 | 2.21 | <0.05 | - |
| ***Zero-Inflation Model*** | | | | | |
| Constant | 42.80 | 14.12 | 3.03 | <0.01 | - |
| DNCC1 | -0.63 | 0.18 | -3.48 | <0.01 | 0.53 |
| DEWP3 | -1.78 | 0.58 | -3.09 | <0.01 | 0.17 |
| DEWP4 | 1.27 | 0.52 | 2.43 | <0.05 | 3.56 |
| DEWP9 | -1.26 | 0.43 | -2.95 | <0.01 | 0.28 |
| WDSP10 | -1.89 | 0.69 | -2.74 | <0.01 | 0.15 |
| WDSP11 | 1.61 | 0.71 | 2.25 | <0.05 | 4.98 |

DNCC1: daily new COVID-19 cases at 1 lag; DEWP (2, 3, 4, 9, 10, 12): dew point at lag 0 (lag 2, lag 3, lag 4, lag 9, lag 10, lag 12); WDSP (9, 10, 11, 12, 13, 14): wind speed at lag 0 (lag 9, lag 10, lag 11, lag 12, lag 13, lag 14); IRR: incidence rate ratio; NaN: not a number

© COPYRIGHT UPM

# CHAPTER 5

# DISCUSSION

## 5.1 Zero-Inflated Negative Binomial Model

Zero-inflated negative binomial (ZINB) model has been widely used to study several diseases such as COVID-19 and foot-and-mouth disease (Gao et al., 2016; Iqbal et al., 2022; Jafarzadeh et al., 2014; C. Wang et al., 2014). ZINB model is preferred when the dependent variable has excessive zeros and overdispersion (Table 7) (Paulo Fávero et al., 2021). In this study, the dependent variable, daily new COVID-19 cases, was validated as having excessive zeros (observed zero and predicted zero in the Poisson model is 40 and 0 respectively) and overdispersion (significant overdispersion test at 1% level of significance). Therefore, negative binomial and ZINB model were proposed in the first place and then confirmed the final model by a series of tests. The intraclass correlation coefficient (ICC) that represents the reliability of the fitted ZINB model was only 0.592, suggesting moderate reliability. However, previous studies were able to establish the reliability of a zero-inflated model up to 0.922 (Gao et al., 2016; C. Wang et al., 2014). Nevertheless, the deployment of ZINB model that took overdispersion and zero-inflation of the dependent variable into account in this COVID-19 study shall provide a new insight for future local researchers.

There are two parts of the output of the ZINB model. The first part of the output represents the count model which describes the effect of the predictor variables on



© COPYRIGHT UPM

COVID-19 cases, whereas the second part represents the zero-inflation model which describes the odds of having zero cases. Since this study focuses on the effect of the meteorological variables on daily new COVID-19 cases, the zero-inflation model will not be further discussed.

**Table 7. Model selection guideline for over-dispersed and zero-inflated dependent variable.**

| Dependent Variable | | Model |
|---|---|---|
| **Overdispersion** | **Zero Inflation** | |
| No | No | Poisson |
| Yes | No | Negative Binomial |
| No | Yes | Zero-Inflated Poisson |
| Yes | Yes | Zero-Inflated Negative Binomial |

## 5.2 Effect of Meteorological Factors on COVID-19 cases

The present study that employed a longer observation period, 25th January 2020 to 22nd May 2022, to investigate the relationship between the meteorological factors with COVID-19 cases may provide a new perspective as most of the previous study period was short (Daud & Syed Jamaludin, 2021; Lloyd & Viswanathan, 2022; Makama & Lim, 2021; Tan et al., 2021). In addition, we established a location-specific study in Malaysia's most populous state, which may assist local policymaking.



© COPYRIGHT UPM

### 5.2.1 Effect of Temperature on COVID-19 cases

In this study, temperature was found to be negatively correlated with daily new COVID-19 cases. This study also revealed no significant lag effects between temperature and COVID-19 cases. Hence, temperature was not considered to model its lag effect. The previous studies in Malaysia support the findings of this study, where the rise in temperature is claimed to reduce SARS-CoV-2 transmission in Malaysia (Lloyd & Viswanathan, 2022; Suhaimi et al., 2020). A study from Selcuk et al. (2021) not only reported a negative correlation that is inconsistent with our findings but also revealed a significant negative effect at lag 0, lag 3, lag 7 and lag 14.

It is also interesting to note that there is contradiction with a study done in Kuala Lumpur (Makama & Lim, 2021). Makama and Lim (2021) reported that 1°C rise in temperature (>29.7°C) increases the daily cases by 1.024% and 1.462% at lag 7 and lag 28, respectively. In addition, Tan et al. (2021) explored the relationship between ambient temperature and daily COVID-19 cases in all states of Malaysia and reported a non-significant positive correlation. Furthermore, several studies in other tropical countries such as Indonesia (Tosepu et al., 2020), Singapore (Pani et al., 2020), and Brazil (Prata et al., 2020) also suggested that higher temperature promote the spread of COVID-19. The findings from Prata et al. (2020) showed that every increase of 1°C for temperature below 25.8°C will decrease COVID-19 cases by 4.89% in Brazil. Xie and Zhu (2020) studied the relationship between temperature and COVID-19 across 122 Chinese cities in China also revealed that that 1°C rise in temperature is associated with a 4.861% increase in the daily confirmed cases. Such difference was believed to be due to the longer study period used in this study.



© COPYRIGHT UPM

### 5.2.2 Effect of Relative Humidity on COVID-19 cases

Relative humidity is the percentage of the water vapour content in the air compared to the fully saturated water vapour content in the air at a particular temperature. In this study, relative humidity exhibits a weak significant negative correlation with the COVID-19 cases in Kendall rank correlation test. This result is consistent with the studies conducted by Bashir et al. (2020) at the United State, Selcuk et al. (2021) and Şahin (2020) at Turkey, and Ahmadi et al. (2020) at Iran, suggesting a lower COVID-19 case count at high relative humidity.

This may be explained by the rapid evaporation of the low water vapour content, making the viral-laden droplets smaller and free to suspend and travel in the air for a longer time (Ahlawat et al., 2020; Cai et al., 2007; Guo et al., 2020). In addition, dry air may have a damaging effect on the human respiratory tract and respiratory immunity, increasing the risk of infection in the susceptible individuals (Ahlawat et al., 2020; Lowen et al., 2007).

Moreover, a high correlation was found with other meteorological variables, i.e. mean temperature, dew point, precipitation, and wind speed. Therefore, to avoid multicollinearity, relative humidity is not introduced in the modelling as a predictor variable in this study. This agreed on the monotonic relationship between temperature and relative humidity (Dotson, 2018). It is important to note that several studies that successfully studied the relationship between relative humidity and COVID-19 cases, together with other meteorological factors, deployed only correlation test (Pani et al., 2020; M. L. Tan et al., 2021; Tosepu et al., 2020) or other



© COPYRIGHT UPM

methods like Generalized Additive Model (He et al., 2021). However, as a regression model was deployed in this study, multicollinearity must be minimised by excluding the multicollinear explanatory variables (Kim, 2019).

### 5.2.3 Effect of Dew Point on COVID-19 cases

Dew point is known as the temperature in which the air needs to be cooled down to in order to achieve fully saturated water vapour in the air. In the present study, dew point has a negative correlation with the number of daily new COVID-19 cases. The number of cases decreases by 0.85 times for every one-degree-Celsius increase in dew point at lag 0 at lag 2, while the number of cases decreases by 0.82 times for every one-degree-Celsius increase in dew point at lag 10, and lag 12, when other variables are held constant. This means it is less likely to have COVID-19 cases as the dew point at lag 0, lag 9, lag 11, and lag 13 increase. This agrees with two studies conducted in Turkey with lags up to 14 days, although with lower dew point range (-1.4 ℃ to 10.00 ℃) compared to Malaysia (Şahin, 2020; Selcuk et al., 2021).

However, when it comes to other countries with similar climate to Malaysia or even within Malaysia, the findings showed a positive correlation between dew point and COVID-19 cases, which contradicts this study. (Lloyd & Viswanathan, 2022; Pani et al., 2020). According to Lloyd and Viswanathan (2022), the number of COVID-19 cases is higher at dew point 23.80 ℃ to 24.75 ℃. The contradiction between the present study and Lloyd and Viswanathan (2022) and Pani et al. (2020) might be due to a longer observation period of the present study and the wider span of dew point (19.42 ℃ to 26.58 ℃). A global study that investigated the influence of



© COPYRIGHT UPM

meteorological factors including dew point on the COVID-19 cases within the top 20 countries of COVID-19 pandemic claimed that the number of COVID-19 cases would increase by 11% for every 1% increase in dew point.

### 5.2.4 Effect of Precipitation on COVID-19 cases

Precipitation occurs in Malaysia when it rains. The result showed that precipitation was not significant negatively correlated with the daily new COVID-19 cases. Several studies also suggested an insignificant correlation between precipitation and COVID-19 (Auler et al., 2020; Bashir et al., 2020; Rendana, 2020; M. L. Tan et al., 2021; Tosepu et al., 2020). According to Menebo (2020), it is suggested that people avoid going out on rainy days reducing the spread of COVID-19. As there is no significant correlation between precipitation and COVID-19 cases, it was not taken into account to model its effect at up to 14 lags on the COVID-19 cases.

### 5.2.5 Effect of Wind Speed on COVID-19 cases

Wind speed is often associated with airborne transmission of SARS-CoV-2 as wind carries the viral-laden aerosols to different destinations, and wind speed determines how far the aerosols travel (van Doremalen et al., 2020). This study demonstrated a significant positive correlation between wind speed and the number of daily new COVID-19 cases. Several studies in Malaysia also showed a consistent positive correlation between wind speed and COVID-19 cases (Daud & Syed Jamaludin, 2021; Lloyd & Viswanathan, 2022; Makama & Lim, 2021; Tan et al., 2021). In



© COPYRIGHT UPM

Malaysia, COVID-19 cases is more likely to increase at wind speed between 1.4 m/s and 2.7 m/s (Lloyd & Viswanathan, 2022).

The decrease of wind speed is associated with an increase of the number of COVID-19 cases. The COVID-19 cases decrease by 0.884. 0.924, 0.913, 0.929, 0.927, and 0.915 for a one-unit increase in wind speed at lag 9, lag 10, lag 11, lag 12, lag 13, and lag 14, respectively, when other variables are held constant. The result showed a slight contradiction with a study conducted in Turkey that demonstrated that higher wind speed at lag 0 decreases the number of cases whereas increases the number of cases lag 3, lag 7, and lag 14 (Şahin, 2020). However, another more recent study in Turkey claimed that only wind speed at lag 0, lag 3, lag 7 decreases the number of cases whereas increases the number of cases at lag 14 (Selcuk et al., 2021). The difference of results in these study might be due to the different number of regions was included in the study. The present study only includes Selangor state of Malaysia, while Şahin (2020) includes 11 cities and Selcuk et al. (2021) includes 81 provinces in Turkey in their study.

## 5.3 Inclusion of daily new COVID-19 cases at lag 1 as the predictor variable

Quasi-complete separation occurs when the outcome variable separates a predictor variable or a combination of predictor variables to a certain degree. The quasi-complete separation can be ignored as the maximum likelihood for other predictor variables are still valid. However, ignoring quasi-complete separation fails to obtain the correct coefficient for daily new COVID-19 cases at lag 1 to predict the number



© COPYRIGHT UPM

of daily new COVID-19 cases effectively (UCLA: Statistical Consulting Group, n.d.). Nevertheless, daily new COVID-19 cases at lag 1 only plays a role to control the autocorrelation of the COVID-19 cases, so it is not essential to obtain the coefficient. Moreover, the inclusion of daily new COVID-19 cases at lag 1 as the independent variables was validated by likelihood ratio test (LRT).

© COPYRIGHT UPM

# CHAPTER 6

# CONCLUSION

## 6.1 Conclusion

The present study has established the relationship of the meteorological factors on the daily new COVID-19 cases in Selangor, Malaysia. Temperature, relative humidity, dew point, and wind speed are significantly and negatively correlated with the daily new COVID-19 cases. In terms of lag effects, the daily new COVID-19 cases were significantly decreased for a one-unit increase in dew point at lag 0, lag 2, lag 10, and lag 12, wind speed at lag 9, lag 10, lag 12, lag 13, and lag 14, when other variables are held constant.

## 6.2 Limitations of the Study

This study has a few potential limitations:

1. The weather data may not be the most accurate data, as the data was not obtained from official source, i.e. Malaysian Meteorological Department. This might affect the statistical analyses.
2. The number of COVID-19 cases is not only dependent on weather factors but also other factors such as air pollution, population density, governmental policies, public health measures and testing rate. Hence, more variables shall be examined for a more comprehensive study.

© COPYRIGHT UPM

### 6.3 Recommendations for Future Studies

Based on the findings of the present study, there are several recommendations to be considered for future studies:

1. Identifying any interactions between the predictor variables.
2. Looking into other meteorological variables such as solar radiation and air pressures that affect the spread of COVID-19, considering the location of Malaysia near the equator and has a tropical climate.
3. Exploring and introducing the confounding variables such as air pollution index, air-conditioning use, holidays, government response stringency index, implementation of movement restriction control, and public health measures in the model.

© COPYRIGHT UPM

# REFERENCES


Abdullah, N. H. (2020a). *Situasi Semasa Jangkitan Penyakit Coronavirus 2019 (COVID-19) di Malaysia, 4 Mac 2020*. https://kpkesihatan.com/2020/03/04/kenyataan-akhbar-kpk-4-mac-2020-situasi-semasa-jangkitan-penyakit-coronavirus-2019-covid-19-di-malaysia/

Abdullah, N. H. (2020b). *Situasi Semasa Jangkitan Penyakit Coronavirus 2019 (COVID-19) di Malaysia, 8 Julai 2020*. https://kpkesihatan.com/2020/07/08/kenyataan-akhbar-kpk-8-julai-2020-situasi-semasa-jangkitan-penyakit-coronavirus-2019-covid-19-di-malaysia/

Abdullah, N. H. (2022). *Situasi Semasa Jangkitan Penyakit Coronavirus 2019 (COVID-19), 1 April 2022*. https://kpkesihatan.com/2022/04/01/kenyataan-akhbar-kpk-1-april-2022-situasi-semasa-jangkitan-penyakit-coronavirus-2019-covid-19/

Ahlawat, A., Wiedensohler, A., & Mishra, S. K. (2020). An overview on the role of relative humidity in airborne transmission of sars-cov-2 in indoor environments. *Aerosol and Air Quality Research*, *20*(9), 1856–1861. https://doi.org/10.4209/aaqr.2020.06.0302

Ahmadi, M., Sharifi, A., Dorosti, S., Jafarzadeh Ghoushchi, S., & Ghanbari, N. (2020). Investigation of effective climatology parameters on COVID-19 outbreak in Iran. *The Science of the Total Environment*, *729*. https://doi.org/10.1016/J.SCITOTENV.2020.138705

Alduchov, O. A., & Eskridge, R. E. (1996). Improved Magnus form approximation of saturation vapor pressure. *Journal of Applied Meteorology*, *35*(4), 601–609. https://doi.org/10.1175/1520-0450(1996)035<0601:IMFAOS>2.0.CO;2

Anand, R. (2021, March 2). Malaysia lifts MCO as cases taper down, vaccination drive kicks in. *The Straits Times*. https://www.straitstimes.com/asia/se-asia/malaysia-lifts-mco-for-kl-selangor-johor-and-penang

Anggreainy, M. S., Illyasu, A. M., Musyaffa, H., & Kansil, F. H. (2022). Analysis of Factors Influencing the COVID-19 Mortality Rate in Indonesia using Zero Inflated Negative Binomial Model. *International Journal of Advanced Computer Science and Applications*, *13*(4), 728–734. https://doi.org/10.14569/IJACSA.2022.0130485

Auler, A. C., Cássaro, F. A. M., da Silva, V. O., & Pires, L. F. (2020). Evidence that high temperatures and intermediate relative humidity might favor the spread of COVID-19 in tropical climate: A case study for the most affected Brazilian cities. *Science of The Total Environment*, *729*, 139090. https://doi.org/10.1016/J.SCITOTENV.2020.139090


© COPYRIGHT UPM

Bashir, M. F., Ma, B., Bilal, Komal, B., Bashir, M. A., Tan, D., & Bashir, M. (2020). Correlation between climate indicators and COVID-19 pandemic in New York, USA. *Science of The Total Environment*, *728*, 138835. https://doi.org/10.1016/J.SCITOTENV.2020.138835

Bernama. (2020, April 17). COVID: Malaysia has not entered the fourth wave - Dr Adham. *Bernama*. https://bernama.com/en/general/news_covid-19.php?id=1953178

Botsch, R. E. (2011). *Chapter 12. Significance and Measures of Association*. http://polisci.usca.edu/apls301/Text/Chapter 12. Significance and Measures of Association.htm

Butcher, K., Crown, L., & Gentry, E. J. (2006). The International System of Units ( SI ) – Conversion Factors for General Use. *Natl. Inst. Stand. Technol. Spec. Pub.*, *1038*, 24. https://doi.org/10.6028/NIST.SP.1038

Cai, Q. C., Lu, J., Xu, Q. F., Guo, Q., Xu, D. Z., Sun, Q. W., Yang, H., Zhao, G. M., & Jiang, Q. W. (2007). Influence of meteorological factors and air pollution on the outbreak of severe acute respiratory syndrome. *Public Health*, *121*(4), 258. https://doi.org/10.1016/J.PUHE.2006.09.023

Cameron, A. C., & Trivedi, P. (2020). *overdisp: Overdispersion in Count Data Multiple Regression Analysis*. https://cran.r-project.org/package=overdisp

Cameron, A. C., & Trivedi, P. K. (1990). Regression-based tests for overdispersion in the Poisson model. *Journal of Econometrics*, *46*(3), 347–364. https://doi.org/10.1016/0304-4076(90)90014-K

Chan, K. H., Peiris, J. S. M., Lam, S. Y., Poon, L. L. M., Yuen, K. Y., & Seto, W. H. (2011). The effects of temperature and relative humidity on the viability of the SARS coronavirus. *Advances in Virology*, *2011*. https://doi.org/10.1155/2011/734690

Chang, L., Zhao, L., Gong, H., Gong, H., Gong, H., Wang, L., Wang, L., Wang, L., Yang, Z., & Xu, B. (2020). Severe Acute Respiratory Syndrome Coronavirus 2 RNA Detected in Blood Donations. *Emerging Infectious Diseases*, *26*(7), 1631. https://doi.org/10.3201/EID2607.200839

Chen, B., Liang, H., Yuan, X., Hu, Y., Xu, M., Zhao, Y., Zhang, B., Tian, F., & Zhu, X. (2020). Roles of meteorological conditions in COVID-19 transmission on a worldwide scale. *MedRxiv*, 2020.03.16.20037168. https://doi.org/10.1101/2020.03.16.20037168

Chen, S., Prettner, K., Kuhn, M., Geldsetzer, P., Wang, C., Bärnighausen, T., & Bloom, D. E. (2021). Climate and the spread of COVID-19. *Scientific Reports 2021 11:1*, *11*(1), 1–6. https://doi.org/10.1038/s41598-021-87692-z

© COPYRIGHT UPM

Chen, W. H., Strych, U., Hotez, P. J., & Bottazzi, M. E. (2020). The SARS-CoV-2 Vaccine Pipeline: an Overview. *Current Tropical Medicine Reports*, *7*(2), 61–64. https://doi.org/10.1007/S40475-020-00201-6

Chirumbolo, S., Pandolfi, S., & Valdenassi, L. (2022). Seasonality of COVID-19 deaths. Did social restrictions and vaccination actually impact the official reported dynamic of COVID-19 pandemic in Italy? *Environmental Research*, *212*, 113229. https://doi.org/10.1016/J.ENVRES.2022.113229

Chowdhuri, I., Pal, S. C., Arabameri, A., Ngo, P. T. T., Roy, P., Saha, A., Ghosh, M., & Chakrabortty, R. (2022). Have any effect of COVID-19 lockdown on environmental sustainability? A study from most polluted metropolitan area of India. *Stochastic Environmental Research and Risk Assessment*, *36*(1), 283–295. https://doi.org/10.1007/s00477-021-02019-8

Chowdhury, F. R., Ibrahim, Q. S. U., Shafiqul Bari, M., Jahangir Alam, M. M., Dunachie, S. J., Rodriguez-Morales, A. J., & Ismail Patwary, M. (2018). The association between temperature, rainfall and humidity with common climate-sensitive infectious diseases in Bangladesh. *PLoS ONE*, *13*(6). https://doi.org/10.1371/JOURNAL.PONE.0199579

Chowdhury, S. D., & Oommen, A. M. (2020). Epidemiology of COVID-19. *Journal of Digestive Endoscopy*, *11*(1), 3. https://doi.org/10.1055/S-0040-1712187

Corman, V. M., Landt, O., Kaiser, M., Molenkamp, R., Meijer, A., Chu, D. K. W., Bleicker, T., Brünink, S., Schneider, J., Schmidt, M. L., Mulders, D. G. J. C., Haagmans, B. L., Van Der Veer, B., Van Den Brink, S., Wijsman, L., Goderski, G., Romette, J. L., Ellis, J., Zambon, M., … Drosten, C. (2020). Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. *Euro Surveillance : Bulletin Europeen Sur Les Maladies Transmissibles = European Communicable Disease Bulletin*, *25*(3). https://doi.org/10.2807/1560-7917.ES.2020.25.3.2000045

Daud, S. S., & Syed Jamaludin, S. S. (2021). *Identification of Covid-19 Cases by Cluster Analysis*. *3*, 162–171.

Department of Statistics Malaysia. (2021). *Demographic Statistics Third Quarter 2021, Malaysia*. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=430&bul_id=N05ydDRXR1BJWVlTdDY4TldHd253dz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09

Dotson, J. D. (2018, April 23). *How Temperature & Humidity are Related*. https://sciencing.com/temperature-ampamp-humidity-related-7245642.html

Edinur, H. A., & Safuan, S. (2020). Sri Petaling COVID-19 cluster in Malaysia: challenges and the mitigation strategies. *Acta Bio Medica : Atenei Parmensis*, *91*(4), 1–4. https://doi.org/10.23750/ABM.V91I4.10345

© COPYRIGHT UPM

Fassò, A., Maranzano, P., & Otto, P. (2022). Spatiotemporal variable selection and air quality impact assessment of COVID-19 lockdown. *Spatial Statistics*, *49*, 100549. https://doi.org/10.1016/J.SPASTA.2021.100549

Feng, Y., Marchal, T., Sperry, T., & Yi, H. (2020). Influence of wind and relative humidity on the social distancing effectiveness to prevent COVID-19 airborne transmission: A numerical study. *Journal of Aerosol Science*, *147*, 105585. https://doi.org/10.1016/J.JAEROSCI.2020.105585

Fomby, T. B. (2010). *Stable Seasonal Pattern (SSP) Model*.

Gao, X., Xiao, J., Qin, H., Cao, Z., & Wang, H. (2016). Impact of meteorological factors on the prevalence of porcine pasteurellosis in the southcentral of Mainland China. *Preventive Veterinary Medicine*, *125*, 75–81. https://doi.org/10.1016/J.PREVETMED.2016.01.002

Ghazali, S. M., Singh, S., Zulkifli, A. A., Cheong, Y. L., Md Iderus, N. H., Md Zamri, A. S. S., Ahmad Jaafar, N., Lai, C. H., Wan Mohamed Noor, W. N., Rusli, N., Chong, C. K., Aris, T., Ibrahim, H. M., Dass, S. C., & Gill, B. S. (2022). COVID-19 in Malaysia: Descriptive Epidemiologic Characteristics of the First Wave. *International Journal of Environmental Research and Public Health*, *19*(7). https://doi.org/10.3390/IJERPH19073828

Goswami, K., Bharali, S., & Hazarika, J. (2020). Projections for COVID-19 pandemic in India and effect of temperature and humidity. *Diabetes & Metabolic Syndrome*, *14*(5), 801. https://doi.org/10.1016/J.DSX.2020.05.045

Groß, R., Conzelmann, C., Müller, J. A., Stenger, S., Steinhart, K., Kirchhoff, F., & Münch, J. (2020). Detection of SARS-CoV-2 in human breastmilk. *Lancet (London, England)*, *395*(10239), 1757. https://doi.org/10.1016/S0140-6736(20)31181-8

Guo, Y. R., Cao, Q. D., Hong, Z. S., Tan, Y. Y., Chen, S. D., Jin, H. J., Tan, K. Sen, Wang, D. Y., & Yan, Y. (2020). The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak – an update on the status. *Military Medical Research*, *7*(1), 11. https://doi.org/10.1186/S40779-020-00240-0

Haji Mohd Yassin, M. (2021). *Prime Minister's response to health expert's open letter*. https://www.pmo.gov.my/wp-content/uploads/2021/01/PRIME-MINISTERS-RESPONSE-TO-HEALTH-EXPERTS-OPEN-LETTER.pdf

Hashim, J. H., Adman, M. A., Hashim, Z., Mohd Radi, M. F., & Kwan, S. C. (2021). COVID-19 Epidemic in Malaysia: Epidemic Progression, Challenges, and Response. *Frontiers in Public Health*, *9*, 560592. https://doi.org/10.3389/FPUBH.2021.560592

He, Z., Chin, Y., Yu, S., Huang, J., Zhang, C. J. P., Zhu, K., Azarakhsh, N., Sheng, J., He, Y., Jayavanth, P., Liu, Q., Akinwunmi, B. O., & Ming, W. K. (2021). The influence of average temperature and relative humidity on new cases of COVID-19: Time-Series analysis. *JMIR Public Health and Surveillance*, *7*(1), e20495. https://doi.org/10.2196/20495

Hong, T., Wang, P., & White, L. (2015). Weather station selection for electric load forecasting. *International Journal of Forecasting*, *31*(2), 286–295. https://doi.org/10.1016/J.IJFORECAST.2014.07.001

Hossain, M. S., Ahmed, S., & Uddin, M. J. (2021). Impact of weather on COVID-19 transmission in south Asian countries: An application of the ARIMAX model. *Science of The Total Environment*, *761*, 143315. https://doi.org/10.1016/J.SCITOTENV.2020.143315

Hu, B., Guo, H., Zhou, P., & Shi, Z. L. (2020). Characteristics of SARS-CoV-2 and COVID-19. *Nature Reviews Microbiology 2020 19:3*, *19*(3), 141–154. https://doi.org/10.1038/s41579-020-00459-7

Hu, C. Y., Xiao, L. S., Zhu, H. B., Zhu, H., & Liu, L. (2021). Correlation Between Local Air Temperature and the COVID-19 Pandemic in Hubei, China. *Frontiers in Public Health*, *8*, 1032. https://doi.org/10.3389/FPUBH.2020.604870/BIBTEX

Iqbal, A., Haq, W., Mahmood, T., & Raza, S. H. (2022). Effect of meteorological factors on the COVID-19 cases: a case study related to three major cities of the Kingdom of Saudi Arabia. *Environmental Science and Pollution Research*, *29*(15), 21811–21825. https://doi.org/10.1007/S11356-021-17268-X/TABLES/6

Jackson, C. B., Farzan, M., Chen, B., & Choe, H. (2021). Mechanisms of SARS-CoV-2 entry into cells. *Nature Reviews Molecular Cell Biology 2021 23:1*, *23*(1), 3–20. https://doi.org/10.1038/s41580-021-00418-x

Jafarzadeh, S. R., Norris, M., & Thurmond, M. C. (2014). Prediction of province-level outbreaks of foot-and-mouth disease in Iran using a zero-inflated negative binomial model. *Preventive Veterinary Medicine*, *115*(3–4), 101–108. https://doi.org/10.1016/J.PREVETMED.2014.03.018

Jayaraj, V. J., Rampal, S., Ng, C. W., & Chong, D. W. Q. (2021). The Epidemiology of COVID-19 in Malaysia. *The Lancet Regional Health - Western Pacific*, *17*, 100295. https://doi.org/10.1016/J.LANWPC.2021.100295/ATTACHMENT/ED78EFDB-7456-4CEE-8F99-4CA08D7DF0E8/MMC1.DOCX

Kim, J. H. (2019). Multicollinearity and misleading statistical results. *Korean Journal of Anesthesiology*, *72*(6), 558–569. https://doi.org/10.4097/KJA.19087

© COPYRIGHT UPM

KKMalaysia. (2021). *Kluster #COVID19 yang terbesar di negara ini, Kluster Teratai diisytiharkan tamat hari ini. Kluster ini melibatkan jangkitan di 3 negeri dan 2 wilayah dengan kes positif seramai 7,205 iaitu 589 warganegara dan 6,616 bukan warganegara dan satu kematian.* Twitter. https://twitter.com/kkmputrajaya/status/1383368583984476161

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155. https://doi.org/10.1016/J.JCM.2016.02.012

Kuo, L. (2020, January 21). China confirms human-to-human transmission of coronavirus. *The Guardian*. https://www.theguardian.com/world/2020/jan/20/coronavirus-spreads-to-beijing-as-china-confirms-new-cases

Lackey, M. (2020). *National Centers for Environmental Information Global Surface Summary of day Data*. https://www.ncei.noaa.gov/data/global-summary-of-the-day/

Lin, K., & Marr, L. C. (2020). Humidity-Dependent Decay of Viruses, but Not Bacteria, in Aerosols and Droplets Follows Disinfection Kinetics. *Environmental Science and Technology*, *54*(2), 1024–1032. https://doi.org/10.1021/ACS.EST.9B04959/SUPPL_FILE/ES9B04959_SI_001.PDF

Lloyd, B. N., & Viswanathan, P. M. (2022). A Long Term Observation of Meteorological Influence on COVID-19 Pandemic Spread in Malaysia-A Case Study. **Corresponding Author Journal of Climate Change*, *8*(1), 67–96. https://doi.org/10.3233/JCC220006

Lowen, A. C., Mubareka, S., Steel, J., & Palese, P. (2007). Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature. *PLOS Pathogens*, *3*(10), e151. https://doi.org/10.1371/JOURNAL.PPAT.0030151

Lüdecke, D., Ben-Shachar, M. S., Patil, I., Waggoner, P., & Makowski, D. (2021). performance: An R Package for Assessment, Comparison and Testing of Statistical Models. *Journal of Open Source Software*, *6*(60), 3139. https://doi.org/10.21105/JOSS.03139

Mahdy, M. A. A., Younis, W., & Ewaida, Z. (2020). An Overview of SARS-CoV-2 and Animal Infection. *Frontiers in Veterinary Science*, *7*. https://doi.org/10.3389/FVETS.2020.596391

Makama, E. K., & Lim, H. S. (2021). Effects of Location-Specific Meteorological Factors on COVID-19 Daily Infection in a Tropical Climate: A Case of Kuala Lumpur, Malaysia. *Advances in Meteorology*, *2021*. https://doi.org/10.1155/2021/6675943

© COPYRIGHT UPM

McGraw, K. O., & Wong, S. P. (1996). Forming Inferences about Some Intraclass Correlation Coefficients. *Psychological Methods*, *1*(1), 30–46. https://doi.org/10.1037/1082-989X.1.1.30

Menebo, M. M. (2020). Temperature and precipitation associate with Covid-19 new daily cases: A correlation study between weather and Covid-19 pandemic in Oslo, Norway. *Science of The Total Environment*, *737*, 139659. https://doi.org/10.1016/J.SCITOTENV.2020.139659

Ministry of Health of Malaysia. (2020a). *Empat (4) kluster baharu dilaporkan hari ini*. https://covid-19.moh.gov.my/sorotan/112020/empat-4-kluster-baharu-dilaporkan-hari-ini-07112020

Ministry of Health of Malaysia. (2020b). *Gelombang Ketiga Pandemik COVID-19 di Malaysia*. https://covid-19.moh.gov.my/semasa-kkm/122020/gelombang-ketiga-pandemik-covid-19-di-malaysia

Morawska, L., & Cao, J. (2020). Airborne transmission of SARS-CoV-2: The world should face the reality. *Environment International*, *139*, 105730. https://doi.org/10.1016/J.ENVINT.2020.105730

National Center for Immunization and Respiratory Diseases (NCIRD), D. of V. D. (2021). Scientific Brief: SARS-CoV-2 Transmission. *CDC COVID-19 Science Briefs*. https://www.ncbi.nlm.nih.gov/books/NBK570442/

National Center for Immunization and Respiratory Diseases (NCIRD), D. of V. D. (2022). *Symptoms of COVID-19*. https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html

New Straits Times. (2020, January 25). 3 coronavirus cases confirmed in Johor Baru. *New Straits Times*. https://www.nst.com.my/news/nation/2020/01/559563/breaking-3-coronavirus-cases-confirmed-johor-baru

Nor, S. M. C. M., Shaharudin, S. M., Ismail, S., Zainuddin, N. H., & Tan, M. L. (2020). A comparative study of different imputation methods for daily rainfall data in east-coast Peninsular Malaysia. *Bulletin of Electrical Engineering and Informatics*, *9*(2), 635–643. https://doi.org/10.11591/EEI.V9I2.2090

Ollech, D. (2021). Seasonal Adjustment of Daily Time Series. *Journal of Time Series Econometrics*, *13*(2), 235–264. https://doi.org/10.1515/JTSE-2020-0028/MACHINEREADABLECITATION/RIS

Pan, Y., Zhang, D., Yang, P., Poon, L. L. M., & Wang, Q. (2020). Viral load of SARS-CoV-2 in clinical samples. *The Lancet. Infectious Diseases*, *20*(4), 411. https://doi.org/10.1016/S1473-3099(20)30113-4

© COPYRIGHT UPM

Pani, S. K., Lin, N. H., & RavindraBabu, S. (2020). Association of COVID-19 pandemic with meteorological parameters over Singapore. *The Science of the Total Environment*, *740*, 140112. https://doi.org/10.1016/J.SCITOTENV.2020.140112

Paulo Fávero, L., de Freitas Souza, R., Belfiore, P., Luiz Corrêa, H., C Haddad, M. F., Paulo, L., de Freitas, R., Luiz, H., & C, M. F. (2021). Count Data Regression Analysis: Concepts, Overdispersion Detection, Zero-inflation Identification, and Applications with R. *Practical Assessment, Research, and Evaluation*, *26*, 2021. https://doi.org/10.7275/44nn-cj68

Pejabat Perdana Menteri. (2021). *Pelaksanaan Total Lockdown*.

Prata, D. N., Rodrigues, W., & Bermejo, P. H. (2020). Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil. *Science of The Total Environment*, *729*, 138862. https://doi.org/10.1016/J.SCITOTENV.2020.138862

Rendana, M. (2020). Impact of the wind conditions on COVID-19 pandemic: A new insight for direction of the spread of the virus. *Urban Climate*, *34*, 100680. https://doi.org/10.1016/J.UCLIM.2020.100680

Rothe, C., Schunk, M., Sothmann, P., Bretzel, G., Froeschl, G., Wallrauch, C., Zimmer, T., Thiel, V., Janke, C., Guggemos, W., Seilmaier, M., Drosten, C., Vollmar, P., Zwirglmaier, K., Zange, S., Wölfel, R., & Hoelscher, M. (2020). Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany. *The New England Journal of Medicine*, *382*(10), 970. https://doi.org/10.1056/NEJMC2001468

Şahin, M. (2020). Impact of weather on COVID-19 pandemic in Turkey. *Science of The Total Environment*, *728*, 138810. https://doi.org/10.1016/J.SCITOTENV.2020.138810

Sarkodie, S. A., & Owusu, P. A. (2020). Impact of meteorological factors on COVID-19 pandemic: Evidence from top 20 countries with confirmed cases. *Environmental Research*, *191*, 110101. https://doi.org/10.1016/J.ENVRES.2020.110101

Selcuk, M., Gormus, S., & Guven, M. (2021). Impact of Weather Parameters and Population Density on the COVID-19 Transmission: Evidence from 81 Provinces of Turkey. *Earth Systems and Environment*, *5*(1), 87–100. https://doi.org/10.1007/S41748-020-00197-Z/TABLES/10

Sellers, K. F., & Shmueli, G. (2010). A flexible regression model for count data. *Https://Doi.Org/10.1214/09-AOAS306*, *4*(2), 943–961. https://doi.org/10.1214/09-AOAS306

© COPYRIGHT UPM

Sobral, M. F. F., Duarte, G. B., da Penha Sobral, A. I. G., Marinho, M. L. M., & de Souza Melo, A. (2020). Association between climate variables and global transmission oF SARS-CoV-2. *Science of The Total Environment*, *729*, 138997. https://doi.org/10.1016/J.SCITOTENV.2020.138997

Suhaimi, N. F., Jalaludin, J., & Latif, M. T. (2020). Demystifying a Possible Relationship between COVID-19, Air Quality and Meteorological Factors: Evidence from Kuala Lumpur, Malaysia. *Aerosol and Air Quality Research*, *20*(7), 1520–1529. https://doi.org/10.4209/AAQR.2020.05.0218

Sun, J., Zhu, A., Li, H., Zheng, K., Zhuang, Z., Chen, Z., Shi, Y., Zhang, Z., Chen, S. bei, Liu, X., Dai, J., Li, X., Huang, S., Huang, X., Luo, L., Wen, L., Zhuo, J., Li, Y., Wang, Y., … Li, Y. min. (2020). Isolation of infectious SARS-CoV-2 from urine of a COVID-19 patient. *Emerging Microbes & Infections*, *9*(1), 991. https://doi.org/10.1080/22221751.2020.1760144

Tam, P. C. K., Ly, K. M., Kernich, M. L., Spurrier, N., Lawrence, D., Gordon, D. L., & Tucker, E. C. (2021). Detectable severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in human breast milk of a mildly symptomatic patient with coronavirus disease 2019 (COVID-19). *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, *72*(1), 128–130. https://doi.org/10.1093/CID/CIAA673

Tan, J., Mu, L., Huang, J., Yu, S., Chen, B., & Yin, J. (2005). An initial investigation of the association between the SARS outbreak and weather: with the view of the environmental temperature and its variation. *Journal of Epidemiology & Community Health*, *59*(3), 186–192. https://doi.org/10.1136/JECH.2004.020180

Tan, M. L., Shaharudin, S. M., Samat, N., Tew, Y. L., & Mahamud, M. A. (2021). DISCOVERING DEPENDENCE OF COVID-19 ON WEATHER VARIABLES IN MALAYSIA. *Turkish Journal of Physiotherapy and Rehabilitation*, *32*(2), 2828–2835.

Tang, J. W. (2009). The effect of environmental parameters on the survival of airborne infectious agents. *Journal of The Royal Society Interface*, *6*(SUPPL. 6). https://doi.org/10.1098/RSIF.2009.0227.FOCUS

Thompson, A., & Taylor, B. N. (2008). *NIST Special Publication 811, 2008 edition: Guide for the Use of International System of Units (SI).*

Tosepu, R., Gunawan, J., Effendy, D. S., Ahmad, L. O. A. I., Lestari, H., Bahar, H., & Asfian, P. (2020). Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. *Science of The Total Environment*, *725*, 138436. https://doi.org/10.1016/J.SCITOTENV.2020.138436

UCLA: Statistical Consulting Group. (n.d.). *FAQ What is complete or quasi-complete separation in logistic/probit regression and how do we deal with them?* Retrieved August 15, 2022, from https://stats.oarc.ucla.edu/other/mult-pkg/faq/general/faqwhat-is-complete-or-quasi-complete-separation-in-logisticprobit-regression-and-how-do-we-deal-with-them/

van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E., & Munster, V. J. (2020). Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *New England Journal of Medicine*, *382*(16), 1564–1567. https://doi.org/10.1056/NEJMC2004973/SUPPL_FILE/NEJMC2004973_DISCLOSURES.PDF

Venables, W. N., & Ripley, B. D. (2002). *Modern Applied Statistics with S*. https://doi.org/10.1007/978-0-387-21706-2

Vuong, Q. H. (1989). Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses. *Econometrica*, *57*(2), 307. https://doi.org/10.2307/1912557

Wang, C., Jiang, B., Fan, J., Wang, F., & Liu, Q. (2014). A study of the dengue epidemic and meteorological factors in Guangzhou, China, by using a zero-inflated poisson regression model. *Asia-Pacific Journal of Public Health*, *26*(1), 48–57. https://doi.org/10.1177/1010539513490195

Wang, W., Xu, Y., Gao, R., Lu, R., Han, K., Wu, G., & Tan, W. (2020). Detection of SARS-CoV-2 in Different Types of Clinical Specimens. *JAMA*, *323*(18), 1843–1844. https://doi.org/10.1001/JAMA.2020.3786

Wang, Z., Ma, S., & Wang, C. Y. (2015). Variable selection for zero-inflated and overdispersed data with application to health care demand in Germany. *Biometrical Journal. Biometrische Zeitschrift*, *57*(5), 867–884. https://doi.org/10.1002/BIMJ.201400143

Wei, J. Te, Liu, Y. X., Zhu, Y. C., Qian, J., Ye, R. Z., Li, C. Y., Ji, X. K., Li, H. K., Qi, C., Wang, Y., Yang, F., Zhou, Y. H., Yan, R., Cui, X. M., Liu, Y. L., Jia, N., Li, S. X., Li, X. J., Xue, F. Z., … Cao, W. C. (2020). Impacts of transportation and meteorological factors on the transmission of COVID-19. *International Journal of Hygiene and Environmental Health*, *230*, 113610. https://doi.org/10.1016/J.IJHEH.2020.113610

White, G. C., & Bennetts, R. E. (1996). Analysis of Frequency Count Data Using the Negative Binomial Distribution. *Ecology*, *77*(8), 2549–2557. https://doi.org/10.2307/2265753

Wooldridge, J. M. (2015). Introductory Econometrics 6th Edition. In *Economica* (Vol. 42, Issue 165).

World Health Organization. (2020a). *Breastfeeding and COVID-19*. https://www.who.int/news-room/commentaries/detail/breastfeeding-and-covid-19

World Health Organization. (2020b). *Naming the coronavirus disease (COVID-19) and the virus that causes it*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it



© COPYRIGHT UPM

World Health Organization. (2020c). *Transmission of SARS-CoV-2: implications for infection prevention precautions*. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

World Health Organization. (2020d). *WHO COVID-19 Dashboard*. https://covid19.who.int/

World Health Organization. (2020e). *WHO Director-General's opening remarks at the media briefing on COVID*. https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

World Health Organization. (2021). *COVID-19 in Malaysia: Situation Report, 57*.

World Health Organization. (2022a). *Advice for the public: Coronavirus disease (COVID-19)*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public

World Health Organization. (2022b). *COVID-19 in Malaysia: Situation Report, 76*.

World Health Organization. (2022c). *COVID-19 Weekly epidemiological update, Edition 89, 27 April 2022*.

World Health Organization (WHO) Western Pacific. (2020). *It is now very clear from the latest information that there is at least some human-to-human transmission of #nCoV2019. Infections among health care workers strengthen the evidence for this.* Twitter. https://twitter.com/WHOWPRO/status/1219478544041930752?s=20

Xie, J., & Zhu, Y. (2020). Association between ambient temperature and COVID-19 infection in 122 cities from China. *Science of The Total Environment*, *724*, 138201. https://doi.org/10.1016/J.SCITOTENV.2020.138201

Yaakob, I. S. (2022). *Fasa Peralihan ke Endemik*. https://www.pmo.gov.my/2022/03/kenyataan-media-berkaitan-fasa-peralihan-ke-endemik/

Yang, X.-D., Li, H.-L., Cao, Y.-E., Yang, X.-D. ;, Li, H.-L. ;, & Cao, Y.-E. (2021). Influence of Meteorological Factors on the COVID-19 Transmission with Season and Geographic Location. *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 484*, *18*(2), 484. https://doi.org/10.3390/IJERPH18020484

Zainudin, S., Amiruddin, M., Kassim, M., & Ridza, N. M. (2020). Mitigation Measures during Elections and It's Impacts on COVID-19 Pandemic: Sabah State (Malaysia), New Zealand and the United States. *Borneo Epidemiology Journal*, *1*(2), 145–156. https://doi.org/10.51200/BEJ.V1I2.2748

© COPYRIGHT UPM

Zeileis, A., Kleiber, C., & Jackman, S. (2008). Regression Models for Count Data in R. *Journal of Statistical Software*, *27*(8), 1–25. https://doi.org/10.18637/JSS.V027.I08

Zhang, W., Du, R. H., Li, B., Zheng, X. S., Yang, X. Lou, Hu, B., Wang, Y. Y., Xiao, G. F., Yan, B., Shi, Z. L., & Zhou, P. (2020). Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. *Emerging Microbes and Infections*, *9*(1), 386–389. https://doi.org/10.1080/22221751.2020.1729071/SUPPL_FILE/TEMI_A_1729071_SM6070.XLSX

Zhao, J., Cui, W., & Tian, B. P. (2020). The Potential Intermediate Hosts for SARS-CoV-2. *Frontiers in Microbiology*, *11*. https://doi.org/10.3389/FMICB.2020.580137/FULL

Zhou, N., Dai, H. Y., Zha, W. T., & Lv, Y. (2022). The impact of meteorological factors and PM2.5 on COVID-19 transmission. *Epidemiology & Infection*, *150*, 1–7. https://doi.org/10.1017/S0950268821002570

© COPYRIGHT UPM