ORIGINAL ARTICLE

Assessing the Effect of Rainfall on COVID-19 Transmission in Selangor, Malaysia

Megat Azman Megat Mokhtar[1], Nazri Che Dom[1,2,3], Mohd Iqbal Mohd Nor[3], Samsuri Abdullah[4], Nopadol Precha[5]

[1] Faculty of Health Sciences, Universiti Teknologi MARA (UiTM), UITM Cawangan Selangor, 42300 Puncak Alam, Selangor, Malaysia)
[2] Integrated Mosquito Research Group (I-MeRGe), Universiti Teknologi MARA 12 (UiTM), UITM Cawangan Selangor, 42300 Puncak Alam, Selangor, Malaysia
[3] Institute for Biodiversity and Sustainable Development (IBSD), Universiti 14 Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[4] Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia
[5] Department of Environmental Health and Technology, School of Public Health, Walailak University, Nakhon Si Thammarat, Thailand.

ABSTRACT

Introduction: Growing concern about transmission of COVID-19 in Malaysia has reached new heights, particularly with the recent increase in cases in the Selangor region. In order to shed light on this matter, and in particular to investigate the possible influence of rainfall on the transmission of COVID-19, a comprehensive study was conducted in Selangor, the epicenter of most reported cases. **Methods:** Data for the study were sourced from two primary entities: the Ministry of Health and the Malaysian Meteorological Service. COVID-19 case data encompassing the nine main administrative districts in Selangor. While rainfall data encompassed information on the number of rainy days and the amount of rainfall. The Pearson correlation test was used to evaluate the strength and direction of the correlation between the variables of the COVID -19 cases and the amount of precipitation. **Results:** Analysis revealed a weak correlation between rainfall and COVID-19 cases in Selangor, with no significant correlation found in hotspot or coldspot areas. In hotspot areas, rainy days showed a weak negative correlation (r=-0.131), indicating a slight decrease in COVID -19 cases with increasing number of rainy days. Similarly, rainfall amount had a very weak positive correlation (r=0.046), indicating a minimal increase in COVID-19 cases with more rainfall. In the cold areas, both rainy days and precipitation had a weak negative correlation (r=-0.123 and r=-0.159, respectively), indicating a slight decrease in COVID-19 cases with increasing precipitation. However, these correlations were not statistically significant. **Conclusion:** Understanding the role of weather in disease transmission can also impact risk perception among the public. Future research can explore how weather-related information is communicated to the public and how it may affect individuals' behavior during a pandemic.

Keywords: COVID-19; Correlation; Selangor; Rainfall; Transmission, Malaysia

Corresponding Author:
Megat Azman Megat Mokhtar,
Email: megat729@uitm.edu.my
Tel: +603 3258 4312

INTRODUCTION

The world is currently facing a deadly infectious disease caused by extreme acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as coronavirus disease 2019 (COVID -19). This infectious disease was discovered in Wuhan, China, in December 2019 and has since become one of the greatest public health threats worldwide. On April 10, 2020, the Director-General of the World Health Organization (WHO) stated that the COVID -19 epidemic has affected 213 countries, with 1,524,162 confirmed positive cases and 92,941 deaths. As of January 31, 2021, there have been 214,959 confirmed cases and 760 deaths in Malaysia (1). COVID -19 is an infectious disease that is spread through the air and affects the respiratory tract. The virus is spread primarily through salivary droplets or nasal discharge when an infected person coughs or sneezes (2). The majority of individuals infected with COVID -19 virus had mild to moderate respiratory symptoms and recovered

without requiring specific treatment. Acute respiratory symptoms such as fever, cough, and shortness of breath are common signs and symptoms of COVID -19 infection (3). This infectious disease has also been associated with respiratory failure, multiple organ failure, and in severe cases, death (4).

Similar to other viral respiratory infections, transmission of COVID-19 can be influenced by environmental factors. Numerous researches have been conducted to investigate the influence of climatic factors on the transmission of COVID-19. Lim et al. (2021) found that the transmission of COVID -19 or severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) may also be influenced by environmental factors, including climate and air pollution (5). Previous studies have also found that climatic conditions, i.e., humidity and temperature, can influence disease transmission and mortality rates (6-9). According to Suhaimi et al. (2020) and Sangkham et al. (2021), air pollution is also a good predictor of transmission of COVID-19 (10-11). Breathing polluted air affects the respiratory system and worsens the health status of people infected with COVID -19 disease. As of June 30, 2021, the Malaysian Ministry of Health (MOH) reported that Selangor had the highest number of COVID-19 cases with 248,751 cumulative cases, 22 deaths, and 2,205 recoveries. According to the ministry's statistics, the highest number of reported cases, 1,037, came from Petaling in Selangor.

The rapid outbreak of COVID-19 cases is a cause of public concern. However, COVID -19 is a new disease, and the factors affecting its transmission are still unclear (12). Climate is one factor that affects disease transmission, while rainfall is an important variable that has always been used in research to determine if it correlates with communicable diseases. Therefore, the aim of this study was to determine the impact of rainfall on the transmission of COVID-19 in Selangor in order to reduce the number of cases transmitted and to determine the correlation between COVID-19 and rainfall. Recent studies examining the relationship between weather and COVID-19 have identified rainfall as a key environmental variable alongside temperature and humidity. These studies have suggested that rainfall can play a significant role in mitigating or exacerbating the spread of the virus, depending on local conditions and regional climate patterns. Therefore, exploring the relationship between rainfall and COVID-19 transmission is not only justified but also aligned with the emerging trends in the literature on environmental factors influencing the pandemic. Thus, investigating the role of rainfall in COVID-19 transmission is essential as it encompasses a range of interrelated factors that can either hinder or facilitate the spread of the virus. This comprehensive exploration aims to contribute valuable insights to our understanding of COVID-19 dynamics and inform public health strategies aimed at controlling and mitigating the impact of the pandemic.

MATERIALS AND METHODS

Study Population: The study was conducted in the state of Selangor in Peninsular Malaysia, which has a total drainage area of approximately 2,287 km2. It is located between longitude 101.5183° E and latitude 3.0738° N. This state is divided into nine main administrative districts, namely Sabak Bernam, Kuala Selangor, Klang, Kuala Langat, Sepang, Hulu Langat, Petaling, Gombak and Hulu Selangor. Selangor is the most populous state (5.46 million inhabitants), and Shah Alam, which had 481 654 inhabitants in 2020, is the capital of Selangor. Shah Alam, with coordinates between 3°05′48.74″ N, 101°33′02.39″ E and 2°58′22.93″ N, 101°44′39.69″ E, is located 25 km and 45 minutes from Kuala Lumpur. This study focused on the entire state of Selangor (Figure 1).

Figure 1 : The geographical representation the area of interest of this study which is Selangor map based on district. X mark represented meteorological station in Selangor.

Selangor, with its high population density, is of great public health importance in terms of communicable disease control and prevention. Selangor was selected for this study because an increasing number of COVID-19 cases are still reported in all districts of Selangor. Temperatures in Selangor are high on average, with April being the hottest month with an average maximum temperature of 33ºC. Generally, there are several rainy seasons during the year, which is crucial in determining the rainfall distribution pattern. Apart from this, Selangor is a state with rapid industrial growth. Many industries in Selangor are important to Malaysia's economic sustainability. More industries need to be developed that affect a large number of people. As the population grows, the

likelihood of close contact also increases, which will favour the spread of the disease COVID-19. Therefore, Selangor was an ideal location for research on the transmission of COVID-19 infections.

Study Design

In this study, an integrated epidemiologic research approach was used to evaluate the impact of precipitation patterns on COVID -19 transmission. A retrospective cross-sectional study was conducted from August 2020 to July 2021 to analyse data obtained from the Ministry of Health and the Malaysian Meteorological Service. This study included data (i) on COVID-19 cases in Selangor and (ii) on rainfall from the Meteorological Department, with differences in district location and time. Surveillance data on COVID -19 cases from the nine main administrative districts in Selangor and data on daily COVID -19 cases from August 2020 to July 2021 were collected from the Ministry of Health. The Malaysian Meteorological Department provided meteorological data on rainfall patterns in Selangor. Rainfall days and rainfall amount were included in the statistics.

Data Collection and Management

Data are from reports of confirmed cases published by the Malaysian Ministry of Health for each district in Selangor on a daily basis from August 2020 to July 2021. These reports to the nearest district health office came from all registered physicians before being recorded as confirmed diagnosed cases. The COVID-19 cases were recorded daily before being converted to weekly statistics. Rainfall data were obtained from the Malaysian Meteorological Department. Rainfall was measured in millimetres (mm) based on average daily records. Precipitation data were recorded daily before being converted to weekly statistics.

Two main data sources were used in this study: (i) data on COVID -19 cases were obtained as secondary data from the Ministry of Health, and (ii) data on rainfall were obtained from the Malaysian Meteorological Department of the Ministry of Science, Technology and Innovation. Data on daily cases were collected from August 2020 to July 2021, and a database of cases was created for all nine major districts in Selangor State. Variables included confirmed COVID -19 cases reported daily from all districts in Selangor. Rainfall data recorded by the local station in Selangor for each district and one of the local stations in Subang (with latitude: 3° 08′ N, longitude: 101° 33′ E, elevation: 16.6 m) from August 2020 to July 2021 were recorded in Microsoft Excel format. Details of the dataset on the distribution of COVID -19 cases and variable rainfall data are shown in Table I.

Table I : Datasets and their attributes

Datasets	Sources	Specifications	Attributes	Value	Being pre-processed
COVID-19 cases data	Ministry of Health Malaysia	Daily aggregated data; ▪ Dates ▪ Districts	Data time interval	2020/August – 2021/July	Weekly based was converted 9 main administrative districts
			Size	Districts in Selangor	
			Week	1 - 53	
			District Sub-districts	9 56	
Weather data	Malaysian Metrological Department, Ministry of Science, Technology	Information include; ▪ Weekly average values of rainfall variables ▪ Station	Data time interval	2020/August – 2021/July	
			Meteorological Station	▪ Tennamaram Estate ▪ Subang ▪ Pertubuhan Peladang Sungai Besar ▪ KLIA Sepang ▪ F.R.I Kepong	
			Rainfall	Mm	Weekly based was converted

Data Analysis

Spatial statistics were used to analyze the distribution of COVID -19 cases in Selangor over a one-year period (August 2020 to July 2021). For the study, ArcMap software was used to generate distribution maps and cluster maps showing the prevalence of COVID -19 cases in different districts. Global Moran's I and local Moran's I statistics were used to identify spatial autocorrelation and disease hotspots. The local Moran's I test used the formation of local indicators of spatial association (LISA) to identify significant spatial clustering of COVID-19 cases, including hotspots, cold spots, and outliers.

Rainfall data from the same period were analyzed to understand rainfall patterns in Selangor. Scatter plots, bar charts, and line plots were created using Origin software to examine the relationship between precipitation and COVID -19 cases. Rainfall data included variables such as maximum, minimum, and average rainfall, as well as the number of rainy days. To determine the correlation between COVID-19 cases and precipitation, a cross-correlation analysis was performed using weekly COVID-19 data and precipitation data. Microsoft Excel and SPSS software were used for the correlation analysis, and the significance level was set at $p < 0.05$. In cases where there were no meteorological stations in the districts, data from nearby stations were used. Overall, the study used spatial statistics, correlation analysis, and graphical representations to examine the distribution of COVID-19 cases and their possible relationship with rainfall patterns in Selangor.

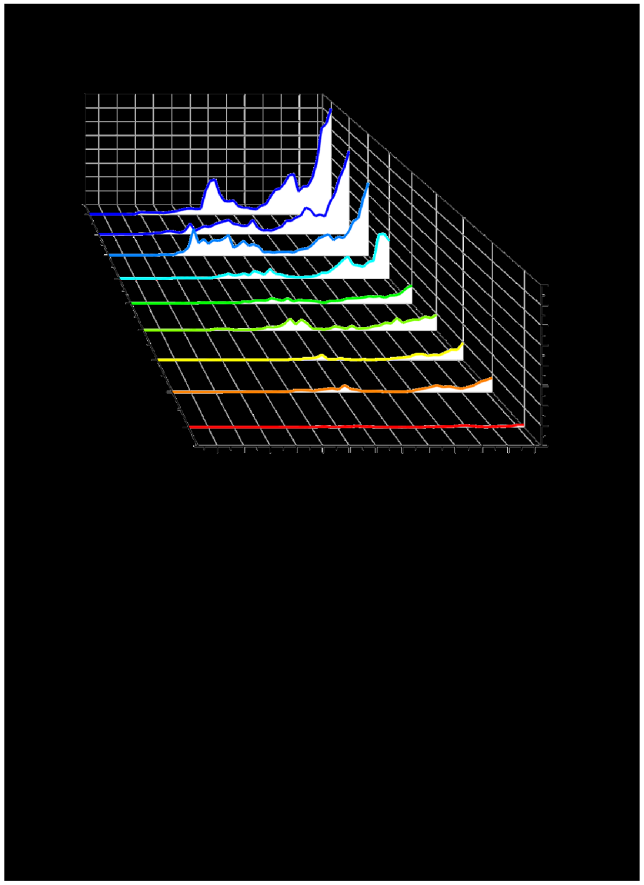

Figure 2 : COVID-19 distribution pattern from August 2020 to July 2021; (A) represented 3D line graph of the distribution pattern for COVID-19 cases and (B) represent descriptive table of COVID-19 cases in Selangor.

RESULTS

The results show that Petaling has the highest number of COVID-19 cases reported over a one-year period from August 2020 to July 2021 with 123,578 cases reported, while Sabak Bernam has the lowest number of cases reported in Selangor with 2,015 cases reported. The number of COVID -19 cases for the 9 districts in Selangor was presented based on epi-weeks. Between August 2020 and July 2021, a total of 400,366 cases were reported. Of these cases, 123,578 (30.87%) were in Petaling, while 84,863 (21.20%) and 78,941 (19.72%) were in Hulu Langat and Klang, respectively. Kuala Selangor and Hulu Selangor recorded the highest number of 1,495 cases (week 30) and 1,874 cases (week 30), respectively.

In addition, data from COVID-19 cases were analysed using Origin software (version 2021) and plotted in a 3D line plot. Figure 2 shows the 3D line plot of the distribution pattern for COVID -19 cases by epi-week for the 9 districts of Selangor from week 31 (2020) to week 30 (2021). The results show that the number of cases increased in Petaling, Hulu Langat and Klang from August 2020 to July 2021. Petaling had the highest number of COVID -19 cases, with a peak of 14,952 reported cases in week 30 (2021). Hulu Langat and Klang also recorded a higher number of COVID-19 cases than the other districts in Selangor, with the maximum number of cases exceeding 9,000, with 11,322 cases (week 30) for Hulu Langat and 9,564 cases (week 30) for Klang. However, the results show that there was a rapid increase in COVID-19 cases in July 2021 in the nine districts of Selangor.

In addition, the chart shows that Sabak Bernam had the lowest number of COVID-19 cases among all nine districts in Selangor, with the maximum number of cases in week 30 (2021) being only 250 cases. Kuala Langat recorded a higher number of COVID-19 cases than Kuala Selangor, where the maximum number of cases in week 30 (2021) for Kuala Langat was 2,197, while Kuala Selangor recorded only 1,495 cases. Apart from this, the chart showed that Gombak had a fluctuating pattern of COVID-19 cases, with a sudden drop in cases from 5,657 cases to 4,770 cases from week 29 to week 30. In addition, Sepang and Hulu Selangor showed a slightly increasing trend, with the maximum number of cases in these two

districts being almost the same at 1,797 and 1,874 cases, respectively.

In this study, a spatial analysis was performed to determine the spatiotemporal distribution pattern of COVID -19 cases in Selangor. Monthly data on COVID -19 cases from August 2020 to July 2021 were used for this spatial analysis. Then, the data were analysed using ArcMap (version 10.8) and plotted according to the sub-districts in Selangor. This analysis was important to determine the potential distribution of COVID -19 cases in each district in Selangor. The spatial distribution was also used to identify the geographic pattern of COVID-19 transmissions. This analysis can help to find case clusters to determine the factors affecting the rapid transmission of COVID -19 disease. Figure 3 shows the spatiotemporal distribution of COVID-19 cases in Selangor based on the analysis of monthly data. The results show that the spatial distribution pattern of COVID-19 transmission was higher in the southern region of Selangor, with Petaling and surrounding areas potentially being high incidence areas. Klang, Damansara and Petaling recorded an increasing number of COVID -19 cases throughout the study period. The number of COVID -19 cases increased from May 2021 to June 2021 in almost all districts in Selangor compared to the previous month. Only eight of the fifty-six sub-districts in Selangor had a high incidence of cases in the last month of the study period. The incidence of COVID-19 cases peaked in uly 2021 in all districts of Selangor, with Petaling recording the highest and Sabak Bernam the lowest. In this study, cluster analysis of COVID -19 distribution was also performed to identify clusters and determine the types of clusters that occurred in Selangor. A global Moran's I test was performed to determine the spatial autocorrelation of COVID-19 transmission and disease hotspots in the sub-districts of the study area. It was important to determine the types of clusters that occurred in the sub-districts of Selangor to identify the distribution pattern of COVID-19 cases. Monthly data on cases from August 2020 to July 2021 were used for this cluster map.

The results of the study are shown in Figure 4. The spatial autocorrelation of COVID -19 cases was assessed using data from cases over one year, and the Global Moran's I test revealed significant and positive spatial autocorrelation in the study area (Global Moran's I index value = 1.126, p-value < 0.001, Z-score = 6.821). The global Moran's I index was used to measure global spatial correlation (13-14). This test showed that there was spatial autocorrelation and clustering of COVID-19 cases

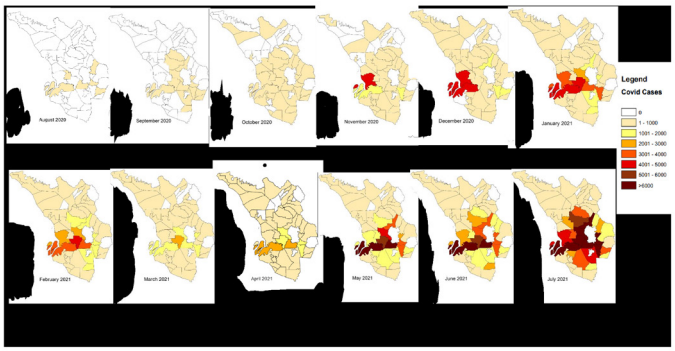

Figure 3 : Spatial-temporal distribution of COVID-19 cases in Selangor from August 2020 to July 2021.

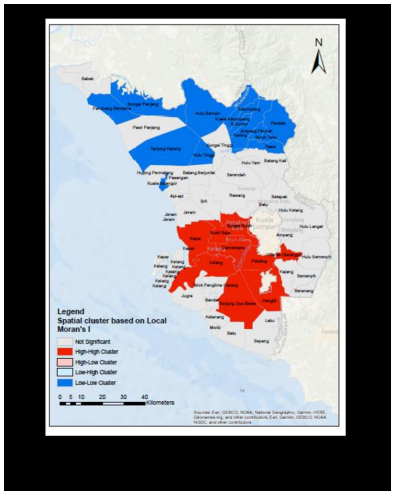

Figure 4 : (A) Subdistrict-level hotspot and cold-spot spatial clusters of COVID-19 cases and (B) Statistically significant subdistrict-level spatial clusters of COVID-19 cases from August 2020 to July 2021.

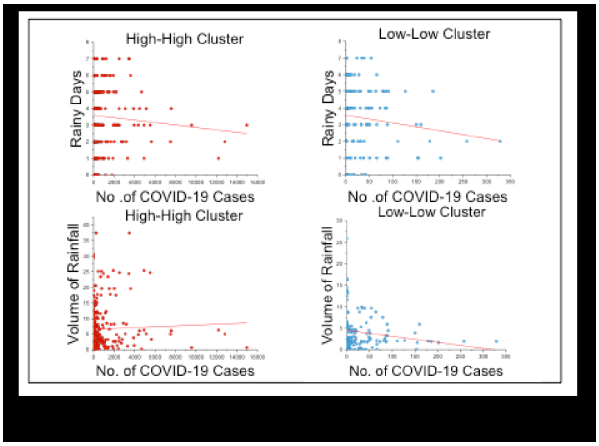

Figure 5 : Correlation graph of rainfall with COVID-19 cases based on high cluster (red) and cold spot (blue) in Selangor.

in the subdistricts of Selangor. In addition, the results showed that there were two types of clusters for one-year COVID-19 cases, namely high-high clusters and low-low clusters. The spatial high-high clusters refer to hot spots for COVID-19 distribution, while the low-low clusters refer to cold spots. The high-high type clusters included nine sub-districts, while the low-low type clusters included fourteen sub-districts in Selangor. All hot spots were located in the southern region, while the cold spots were located in the northern region of Selangor.

In this study, rainfall was used as a variable to determine the relationship between rainfall and COVID-19 cases. The results of the study were used to show the correlation between COVID-19 cases and rainfall in Selangor. The results are shown in the graph in Figure 5, which shows the cases with high and low accumulation of COVID-19 in Selangor. Figure 5 shows the graph of rainy days compared to the number of COVID-19 cases and a graph of rainfall compared to the number of COVID-19 cases. The results show that there is a negative correlation between rainy days and the number of COVID -19 cases in high and low cluster areas in Selangor, with Pearson correlation value of -0.131 in high cluster areas and -0.123 in low cluster areas. In addition, the plot of rainfall versus COVID -19 cases in low cluster areas showed a negative correlation with a Pearson correlation value of -0.159, while the scatter plot in high cluster areas showed a slightly positive Pearson correlation value of 0.046.

DISCUSSION

The spatial analysis of COVID-19 cases in Selangor provides valuable insights that extend beyond mere data visualization. It empowers public health officials and policymakers to take targeted actions, allocate resources efficiently, and tailor interventions to the unique needs of different geographic areas. This approach is crucial for controlling the spread of the virus and mitigating its impact on communities. Spatial analysis can provide insights into the spatial factors contributing to transmission dynamics. It allows researchers and policymakers to explore why certain areas are experiencing higher transmission rates. Factors such as population density, mobility patterns, socioeconomic conditions, and adherence to public health guidelines can be investigated to understand the drivers of transmission.

Several studies have shown that climatic factors have an impact on respiratory viruses, especially COVID -19, which was the focus of interest in this study (15). Therefore, a cross-correlation analysis was conducted to confirm the association between COVID-19 cases and rainfall in Selangor. According to previous studies, meteorological parameters could indicate patterns in the spread of viral diseases at a broad scale, such as close contacts due to population mobility, which could strongly influence the transmission of infectious diseases (16). However, the relationship between climatic conditions and the development of a pandemic may vary depending on the time period considered.

The results of this study showed that there was a weak correlation between COVID-19 cases and rainfall. A weak negative correlation was found for the relationship between rainy days and rainfall with COVID-19 cases in hotspot and coldspot areas in Selangor. Previous studies also found that rainfall was negatively related to daily new deaths, but not significantly related to daily new cases (17). Rainfall is also not correlated with the number of new COVID -19 infections reported daily (18). In addition, this study was supported by the previous research of Tosepu et al. (2020) who reported that meteorological variables, such as rainfall, were insignificantly associated with COVID-19 in Jakarta, Indonesia (3). This is consistent with the results of this study, which found an insignificant correlation between COVID-19 cases and precipitation. The weak correlation suggests that rainfall alone is unlikely to be a major driver of COVID-19 transmission in Selangor. While there were slight negative correlations in hotspot areas and slight positive correlations in cold areas, these relationships were not strong enough to draw meaningful conclusions about the direct impact of rainfall on the virus's spread. The findings highlight the complexity of COVID-19 transmission dynamics.

Menebo (2020) found that low rainfall was positively related to COVID-19 occurrence (19). This result is consistent with a recent study by Ruiz et al. (2010) and Wang et al. (2010) on the effects of rainfall on various viral infections (16, 20). Apart from that, this study was supported by the study of Menebo (2020), which found a negative relationship between precipitation and the occurrence of COVID-19 in Oslo, Norway. This could be due to the fact that people prefer to "stay at home" on rainy days, which reduces interactions between people. On sunny days, on the other hand, people prefer to go outside. As a result, fewer COVID-19 infections are reported on rainy days and more cases are reported on sunny days (high global radiation) (19). Many factors, such as human behaviour, population density, healthcare infrastructure, and public health interventions, play crucial roles in shaping the spread of the virus. Rainfall is just one of many potential contributors. The observed weak correlation between COVID-19 cases and rainfall in Selangor likely results from the interplay of various factors, including human behavior, indoor transmission dynamics, the influence of other weather-related factors, and the effectiveness of public health measures. These complex interactions

underscore the need for a holistic approach to understanding disease transmission, which takes into account multiple variables and their potential synergistic effects. Further research is warranted to explore these mechanisms and their roles in shaping COVID-19 dynamics in different regions.

There are some limitations to this study that should be noted. The rainfall data are from only five meteorological stations, which do not cover all districts in Selangor. This might have affected the statistical analysis conducted and the results obtained might be inaccurate. Another limitation that might have affected the results is the study period (confirmed cases) or the erroneous reporting of daily new cases or daily new deaths in Selangor. In addition, COVID-19 is a new disease that only appeared in 2019, and there are not many studies and information yet. This might have influenced the results of this study. Despite these limitations, this study is genuine and useful in providing a framework for generating further hypotheses about the transmission of COVID-19 infection. However, the results of this study showed a weak association between the occurrence of COVID-19 and rainfall. Therefore, further studies are needed to better understand the factors for rapid transmission of COVID-19 infections.

CONCLUSION

The results of this study show that the amount of precipitation is negatively related to COVID-19 cases. In this study, a weak correlation was found between precipitation and COVID-19 cases, in both hotspot and coldspot areas. It can be concluded that the increasing number of COVID-19 cases was not influenced by the amount of precipitation and rainy days in the study area. However, previous studies have shown that rainfall can affect the transmission of COVID-19. Therefore, further studies are needed to better understand the impact of rainfall on the transmission of COVID -19 infections. The findings of this study could empower policymakers and public health practitioners with actionable insights to better manage and mitigate the impact of COVID-19 in Selangor, offering the potential to save lives, reduce disease burden, and enhance the resilience of the healthcare system during this ongoing pandemic. The data obtained from this study may be useful for further research and may help prevent outbreaks of COVID-19 disease.

REFERENCES

1. Abdullah S, Mansor AA, Napi NNLM, Mansor WNW, Ahmed AN, Ismail M, Ramly ZTA. Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic. Science of the Total Environment, 2020; 729, 139022.
2. Bhadra A, Mukherjee A, Sarkar K. Impact of population density on Covid-19 infected and mortality rate in India. Modeling earth systems and environment, 2020; 1–7. Advance online publication.
3. Tosepu R, Gunawan J, Effendy DS, Ahmad LO, Lestari H, Bahar H, Asfian P. Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. Science of the Total Environment, 2020; 725, 138436.
4. Bashir MF, Ma B, Bilal Komal B, Bashir MA, Tan D, Bashir M. Correlation between climate indicators and COVID-19 pandemic in New York, USA. Science of the Total Environment, 2020; 728, 138835.
5. Lim YK, Kweon OJ, Kim HR, Kim TH, Lee MK. The impact of environmental variables on the spread of COVID-19 in the Republic of Korea. Scientific Reports, 2021; 11(1).
6. Islam ARMT, Hasanuzzaman M, Azad MAK, Salam R, Toshi FZ, Khan MSI, Alam GMM, Ibrahim SM. Effect of meteorological factors on COVID-19 cases in Bangladesh. Environment, Development and Sustainability, 2021; 23(6), 9139–9162.
7 Ma Y, Zhao Y, Liu J, He X, Wang B, Fu S, Yan J, Niu J, Zhou J, Luo B. Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China. Science of the Total Environment, 2020; 724, 138226.
8. Ogaugwu C, Mogaji H, Ogaugwu E, Nebo U, Okoh H, Agbo S, Agbon A. Effect of Weather on COVID-19 Transmission and Mortality in Lagos, Nigeria. Scientifica, 2020; 1–6.
9. Pani SK, Lin NH, RavindraBabu S. (2020). Association of COVID-19 pandemic with meteorological parameters over Singapore. Science of the Total Environment, 2020; 740, 140112.
10. Suhaimi NF, Jalaludin J, Latif MT. Demystifying a Possible Relationship between COVID-19, Air Quality and Meteorological Factors: Evidence from Kuala Lumpur, Malaysia. Aerosol and Air Quality Research, 2020; 20(7), 1520–1529.
11. Sangkham S, Thongtip S, Vongruang P. Influence of air pollution and meteorological factors on the spread of COVID-19 in the Bangkok Metropolitan Region and air quality during the outbreak. Environmental Research, 2021; 197.
12. Briz-Redyn Б, Serrano-Aroca Б. A spatio-temporal analysis for exploring the effect of temperature on COVID-19 early evolution in Spain. Science of the Total Environment, 2020; 728, 138811.
13. de Arruda RMF, Cardoso DT, Teixeira-Neto RG, Barbosa DS, Ferraz RK, Morais M. HF, et al. Space-time analysis of the incidence of human visceral leishmaniasis (VL) and prevalence of canine VL in a municipality of southeastern Brazil: identification of priority areas for surveillance and control. Acta tropica, 2019; 197, 105052.

14. Rendana M, Idris WMR, Abdul Rahim S. Spatial distribution of COVID-19 cases, epidemic spread rate, spatial pattern, and its correlation with meteorological factors during the first to the second waves. Journal of Infection and Public Health, 2021; 14(10), 1340–1348.
15. Rashed, E. A., Kodera, S., Gomez-Tames, J., & Hirata, A. (2020). Influence of absolute humidity, temperature and population density on COVID-19 spread and decay durations: Multi-prefecture study in Japan. International Journal of Environmental Research and Public Health, 17(15), 1–14.
16. Ruiz MO, Chaves LF, Hamer GL, Sun T, Brown WM, Walker ED, Haramis L, Goldberg TL, Kitron UD. Local impact of temperature and precipitation on West Nile virus infection in Culex species mosquitoes in northeast Illinois, USA. Parasites & Vectors, 2010; 3(1), 19.
17. Chaudhary AP, Nelson KA, Nayak L, Sah C. Effect of temperature and precipitation on the daily new cases and daily new death in seven cities around the globe. medRxiv, 2020-10.
18. Sehra, et al. Maximum Daily Temperature, Precipitation, Ultra-Violet Light and Rates of Transmission of SARS- Cov-2 in the United States Shiv', Clinical Infectious Diseases, 2020
19 Menebo MM. 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, 2020; 737, 139659.