EXPLORING THE RELATIONSHIP BETWEEN ENVIRONMENTAL FACTORS AND COVID-19 TRANSMISSION IN SELANGOR, MALAYSIA

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Abstract

The transmission and severity of Coronavirus Disease 2019 (COVID -19) are related to environmental factors such as temperature and humidity. The aim of this study is to investigate the association between daily reported COVID -19 cases and environmental variables. In this study, we used data from October 2020 to October 2021. We used a Generalised Additive Model (GAM) to examine the short-term relationship between COVID -19 and environmental variables in Selangor, Malaysia, using daily meteorological components and daily confirmed COVID -19 cases. We discovered a significant inverse relationship between daily confirmed COVID -19 cases and mean temperature (Tave), relative humidity, wind speed, rainfall, and wind effect index (K), while temperature-humidity index (THI) was significantly associated with an increase in daily confirmed COVID -19 cases. The results of this study provide important insights into the impact that environmental factors may have on the transmission of COVID -19 and should be considered in the development of public health interventions in Selangor, Malaysia.

Keywords: COVID-19, Environmental Factors, Temperature, Humidity, Malaysia

Introduction

COVID-19 is a respiratory infection caused by the SARS-CoV-2 virus that is highly infectious, can cause moderate to severe symptoms, and is potentially fatal. The virus is spread primarily through respiratory droplet infection and close contact and has profound effects on the global population and economy (1, 2). According to studies, environmental variables can have a significant impact on coronavirus transmission and survival (3). Thus, studies have shown that the causative virus of COVID-19', SARS-CoV-2, is more stable in low humidity and colder temperatures, which may contribute to its survival in and in certain locations. Ongoing research will clarify how these variables affect the virus' ability to replicate, survive and cause severe disease. Understanding the importance of environmental variables to the transmission and survival of the virus is critical to developing effective methods to prevent the COVID-19 virus from spreading and future coronavirus outbreaks.

In Hubei Province, China, Qi et al. (3) discovered a strong inverse relationship between temperature and absolute humidity and the frequency of COVID-19 cases. They found that the incidence of cases decreased by 36-57% with each 1°C increase in temperature and by 11-22% with each 1% increase in relative humidity. This suggests that higher temperatures and higher humidity may help prevent the spread of the virus in Hubei province. Studies in other countries have also shown a correlation between reduced COVID-19 transmission rates and higher temperatures. For example, according to a study conducted in Turkey (4), the number of COVID-19 cases decreased as temperature increased. Studies in Mexico (5), Brazil (6), and the United States (7) indicated a similar temperature and COVID-19 transmission have a negative correlation. In contrast, an Australian study (8) found an association between relative humidity and COVID-19 cases, but no correlation between temperature and relative humidity.

Conflicting studies have examined the correlation between temperature, humidity, and COVID-19 transmission. Few studies indicate a negative relationship between COVID-19 transmission and temperature, while others have found no correlation or even a positive correlation. This discrepancy could be due to the complicated relationship between temperature, humidity, and the virus, as well as other variables such as population immunity and human behaviour. Several research from Iran and Spain reported no differences in transmission rates at various temperatures and humidity levels, while research from Brazil reported a flattening of the temperature impact on viral transmission around 25.8 degrees Celsius, indicating that warmer weather did not reduce transmission (9-10). On the other hand, a global study discovered a relationship between higher humidity, higher temperatures, and reduced transmission rates (11). It is also important to note that climate-dependent epidemic simulations have shown that lack of population immunity has a considerably greater role in viral transmission, and summer weather will not greatly slow the spread of the COVID-19 pandemic (12).

While some studies have found a relationship between temperature, humidity, and transmission of COVID-19, this relationship is complicated and may vary depending on location and other circumstances. In addition, it should be noted that weather is not the only factor affecting the spread of the virus. Other measures such as vaccination, testing, and contact tracing, as well as maintaining physical distance and wearing masks, will continue to have a significant impact in preventing the spread of the virus. Research focused on specific areas or cities may provide useful insights into the association between environmental factors and transmission of COVID-19 and enhance public health initiatives to control the spreading of the virus. This study therefore aimed to investigate the influence of these variables on infection rates in Selangor. Selangor is severely impacted by COVID-19, and daily imports of new cases continue. In addition, future research and studies on COVID-19 should provide us with a deeper knowledge of the virus and its behaviour in different environments.

Materials and Methods

Study site and population

This study was conducted in a west coast state of Peninsular Malaysia known as Selangor. Selangor is in the northern part of Perak, Pahang on the east, Negeri Sembilan on the south, and Strait of Malacca on the western part. This state is located between latitude of 3.0738°N and longitude 101.5183°E. This state also consists of nine main administrative districts (Figure 1) and 54 subdistricts. The capital state of Selangor is Shah Alam while Klang is the royal capital. The total area of Selangor is 7,951 km^2 (3,062·2 sq mi) and the total population of Selangor in 2021 was estimated to be 6·56 million·

Figure 1: Map of Selangor showing the nine main administrative districts.

Study design

The daily number of reported COVID-19 cases was the response variable, and one or more predictor variables were examined using a generalised additive time series model (GAM). The phases of the approach are generally as follows: (i) the study would first collect data on daily meteorological factors (temperature, relative humidity, rainfall amount, sunshine duration and wind speed) and confirmed COVID-19 cases in Selangor, Malaysia, between October 2020 and October 2021; (ii) the collected data would then be cleaned and prepared for analysis, which includes removing missing values, outliers, and checking for errors; (iii) a GAM model would then be constructed using appropriate Python software to fit the data.(v) The short-term relationship between COVID-19 and environment variables would then be examined using the model. The influence of environmental variables on the number of confirmed COVID-19 cases can be estimated using the model coefficients, and the statistical significance of such correlations can be assessed using the p-values.

Data analysis

In these types of investigations, the generalised additive model (GAM) is widely utilised. The assumption for a GAM, which models the influence of environmental variables on the number of confirmed COVID-19 cases, is that the

relationship between the environmental variables and the number of confirmed COVID-19 cases is nonlinear and can be represented by smooth functions. In other words, the influence of the environmental variables on the number of confirmed COVID-19 cases is assumed not to be constant but to vary across different values of the environmental variables. This relationship may not be easily captured by a simple linear regression model because the relationship between the response variable (number of confirmed COVID-19 cases) and the environmental variables (such as temperature, relative humidity, rainfall amount and wind speed) may be more complex. To account for this complexity, GAM allows for non-linear relationships between the response and predictor variables by fitting a series of smooth functions to the data. These smooth functions can take many different forms, such as splines, smoothing splines, or local regression. The generalised additive model was employed in combination with conditional Poisson regression to investigate the influence on daily confirmed COVID-19 instances in this research. Environmental and climatic parameters such as rainfall amount, temperature, humidity, sunshine duration, and wind speed were fitted as confounders. The underlying model is outlined below:

$$log[E(Yi)]= \alpha+DOW+bXi+LAT+s(time,df)+s(Ti,df)+s(H,df)+ @s(Ri,df)+s(Vi,df)+s(Qi,df)@)$$

Yi is the number of daily confirmed COVID-19 cases, and E(Yi) is the expected confirmed cases on day i; α is the intercept; DOW is the day of the week; β denotes the exposure–response coefficient; s is a regression spline function; time denotes the days of calendar date; df indicates the degree of freedom and Xi, Hi, Vi, and Qi represent the explanatory variables, sunshine duration, average wind speed, and relative humidity on day i, respectively. We will find strong relationships between the daily confirmed COVID-19 cases and the temperature-humidity index (THI), mean temperature (Tave), and Index of wind effect (K). The following equations were used to determine the temperature humidity index (THI) and the Index of wind effect (K):

$$THI = T_d - 0.55*(1- f)*(T_d - 58)$$

$$K = -(10 \sqrt{V} + 10.45 - V)*(33 - T) + 8.55*H$$

Here, T_d, f, V, T, and H refer to Fahrenheit, relative humidity, mean temperature, average wind speed, and sunshine duration, respectively. The temperature humidity index (THI) is a biometeorological measurement that is based on the heat exchange between the human body and the environment. K is the degree of skin heating under the influence of temperature and wind speed (13). Nine levels were assigned to each of the two indices (Table 1).

Table 1: Standard range of temperature humidity index and index of wind effect

	THI	K
Extremely cold	< 40	<-1200
Cold	40 – 45	-1000 to -1200
Very cool	45 – 55	-800 to -1000
Cool	55 – 60	-600 to -800
Comfort	60 – 65	-400 to -600
Warm	65 – 70	-200 to -400
Very warm	70 - 75	-50 to -200
Hot	75 – 80	80 to -50
Extremely hot	> 80	> 80

Results

Descriptive data of daily confirmed COVID-19 cases and climatic parameters are shown in Table 2. From October 2020 to October 2021, an average of 198 confirmed COVID-19 cases per day were recorded, for a total of 705,206 cases. The daily averages for temperature, maximum and minimum temperature, humidity, precipitation, and wind speed were 28.0 degrees Celsius, 32.6 degrees Celsius, 25.0 degrees Celsius, 71.1%, 8.6 millimetres, and 1.1 metres per second, respectively.

Table 2: Descriptive statistics for daily confirmed coronavirus disease 2019 cases and meteorological factors in Selangor (IQR = Interquartile range)

	Mean	Max	Min	IQR
Daily confirmed cases	198	13	766	559
Temperature (°C)	28.0	30.9	24.0	2.5
Temperature Maximum (°C)	32.6	36.2	24.9	1.4
Temperature Minimum (°C)	25.0	28.1	22.5	2.2
Humidity (%)	71.1	91.7	53.5	12.1
Rainfall (mm)	8.6	111.4	0.0	0.2
Wind Speed (m/s)	1.1	1.8	0.6	0.1

Figure 2 shows the Pearson correlations of the environmental parameters of Selangor. In particular, minimum temperature was positively related to other environmental parameters ($r = 0.30$, $p < 0.05$). There was shown to be a significant positive link between humidity and average, maximum, and minimum temperatures, and negative correlations with rainfall. There was an inverse relationship between wind speed and other variables, however there was a positive relationship between wind speed and humidity.

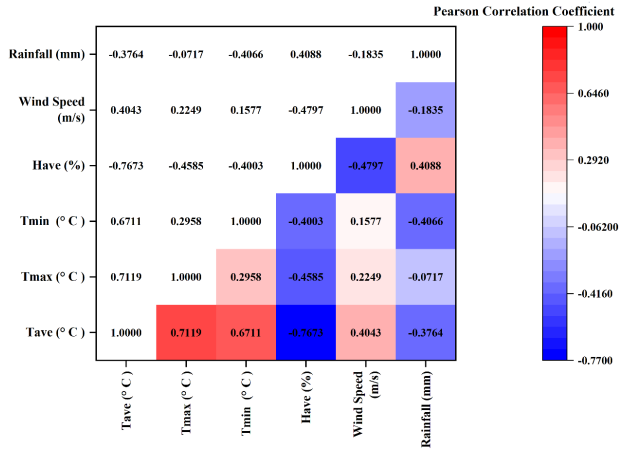

Figure 2: Pearson correlations of environmental factors in Selangor; Note: *p* value less than < 0.05 is significant.

The number of daily confirmed COVID-19 cases was significantly impacted by average temperature, THI, K, and rainfall (Table 3). At p < 0.05, the six factors were statistically significant as explanatory variables. The confirmed COVID-19 cases can be attributed to average temperature, humidity, wind speed, THI, and rainfall, respectively. The adjusted R2 reflects the degree of fit of the model. Six explanatory variables showed a good degree of model fit. Whenever the estimated degree of freedom (Edf) is one (is not equal to 1), the function is linear. The Edf values for average temperature, humidity, wind speed, rainfall, and THI were larger than 1, indicating that the relationship between environmental factors and daily confirmed COVID-19 cases was significantly. The Edf value of all parameter was close to 1, indicating that the relationship between wind speed and rainfall and daily confirmed COVID-19 cases was significantly (p < 0.05). The effect of environmental factors on COVID-19 cases, as predicted using GAM models, is shown in Figure 3.

Table 3: Table 3 Generalized additive model test results between average temperature, humidity, wind speed, rainfall, Temperature humidity index, index of wind effect, rainfall and daily confirmed COVID-19 cases.

	Temperature Average	Humidity	Wind speed	Rainfall	THI	K
Edf	1.003	1.003	1.003	1.005	1.005	1.001
Ref.df	1.005	1.005	1.002	1.001	1.010	1.008
P-Value	0.074	0.064	0.021	0.011	0.073	0.064
Adjusted R^2	0.002	0.002	0.004	0.004	0.002	0.002
Deviance explained	12.2%	13.6%	31.3%	33.2%	53.1%	35.2%

The exposure-response association between daily confirmed COVID-19 cases in Selangor and average temperature, humidity, wind speed, and rainfall shown in Figure 3. Average temperature and relative humidity showed an S-shaped exposure-response relationship with COVID-19. The relationship curve had a slowly increasing trend around T < 28°C, which increased when 25°C < T <30 °C. The relationship curve of wind speed, rainfall amount, and COVID-19 increased in this range. This study found a significant linear decreasing relationship between wind speed, rainfall amount, and COVID-19, suggesting that the daily confirmed COVID-19 cases would have a negative relationship with wind speed and rainfall amount. A decreasing relationship between index of wind effect and COVID-19, indicating that the daily confirmed COVID-19 cases would have a negative association. We found a significantly linear increasing relationship between Temperature Humidity Index and COVID-19.

Discussion

The short-term association between COVID-19 and environment factors in Selangor was investigated in this research. COVID-19 and mean temperature (Tave) showed a positive exposure-response interaction when T was 25°C and a negative relationship when T was 30°C. Consistent with the results of other studies, found that higher temperatures were discovered to have a negative connection with COVID-19 transmission (14, 15). The relationship between temperature and transmission of COVID-19 is complicated and poorly understood. However, there are a number of possible theories as to why higher temperatures might have a negative correlation with COVID-19 transmission. Warmer temperatures could accelerate the degradation of the virus in the environment. This could reduce the likelihood of the virus surviving and spreading. According to studies, the virus may survive for a shorter period of time at higher temperatures and higher humidity. Warmer temperatures may lead to an increase in outdoor activity, which could reduce the likelihood of virus transmission indoors, where the virus can survive for longer periods of time. In addition, people may be less inclined to be indoors in warm weather, reducing the likelihood of transmission.

Low-temperature zones are more vulnerable to infection than high-temperature locations due to people in colder regions spend more time indoors during the winter months, increasing the likelihood of transmission (16). Festivals, activities, and religious rituals that take place indoors are considered an important source of transmission COVID-19. The nations with long and cold winters are more likely to have fast COVID-19 transmission and that transmission rates decrease with warmer temperatures (17). Those who spend more time indoors may have more frequent close contact with others, which may increase the likelihood of spreading the virus. In cold and dry areas, the virus may be able to survive for longer periods of time, which could increase the likelihood of transmission. According to studies, the virus may survive longer in lower temperatures

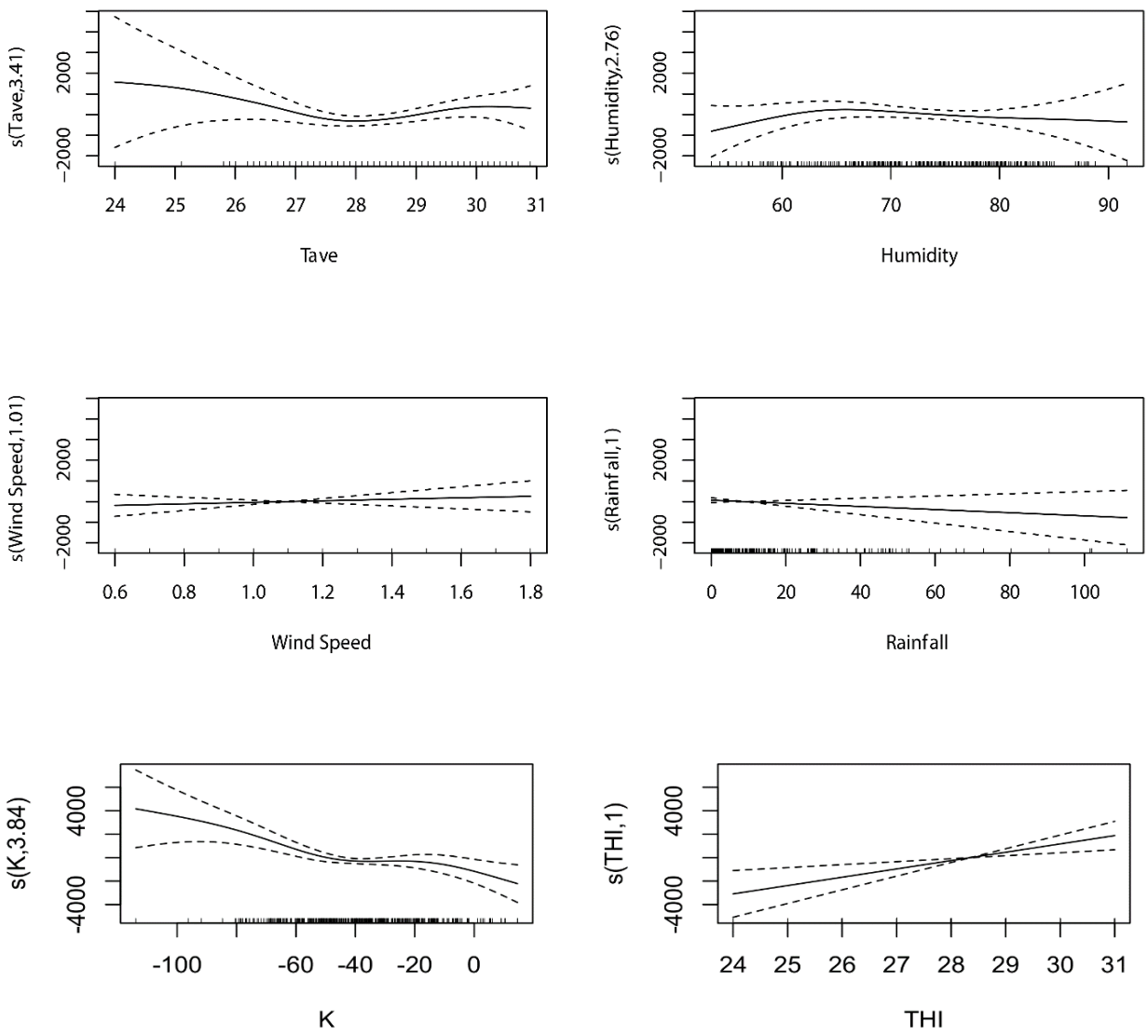

Figure 3: Exposure–response relationship between mean temperature (Tave), humidity, wind speed, rainfall, K, THI and daily confirmed COVID-2019 cases in Selangor.

and relative humidity. In addition, cold temperatures can lead to changes in respiratory function, which could increase susceptibility to infection. When temperatures rise, people are more likely to go outdoors and less likely to stay indoors, which reduces the likelihood of spreading the virus (18, 19). In addition, the sun's UV rays may help reduce the amount of virus particles in the environment, decreasing the likelihood of infection. However, it should be noted that temperature and weather are not the most important factors in the development of COVID-19; other measures such as social isolation, wearing masks, and vaccination are also needed to prevent the spread of the virus.

Humidity levels can affect the stability of the virus, with higher humidity levels tending to reduce the spread of the virus (20, 21). The virus is a type of respiratory virus that is spread through respiratory droplets. When humidity levels are low, the droplets may remain suspended in the air for prolonged periods of time, making it easier for the virus to spread. In contrast, when humidity levels are high, the droplets can become heavy and fall to the ground more quickly, reducing the amount of time that the virus can remain suspended in the air (22). Some studies have found that the virus is less stable in high humidity environments, which can help to slow its spread. For example, one study found that the virus was less stable in environments with relative humidity levels of over 80%, compared to environments with lower humidity levels (4, 23). Another study found that the virus was less stable at high temperatures and high humidity. Several studies have found an association between lower humidity and lower wind speed with the incidence of MERS, SARS-CoV, and COVID-19 (21). These findings suggest that lower humidity and lower wind speed may contribute to the survival and

spread of these viruses. Additionally, several investigations have discovered a positive association between COVID-19 incidence rates and humidity, while others have found a negative association between COVID-19 cases with relative humidity, daily precipitation, and wind speed in humid equatorial climates (24-28).

Biometeorological indices are used to measure human thermal comfort by considering the combined influence of meteorological factors such as temperature, humidity, rainfall and wind speed. The temperature humidity index (THI) and physiologically equivalent temperature (PET) are two regularly used indices (PET or K-index). The THI is calculated by combining temperature and humidity to obtain a single number representing the perceived temperature under specific meteorological conditions. It is used to evaluate the thermal comfort of people under different weather conditions. The K-index, also known as physiologically equivalent temperature (PET), indicates how hot or cold the air feels to the human body. It combines temperature, relative humidity, and wind speed to produce a single number that indicates the thermal comfort of people under different weather conditions. Considering the combined effects of temperature, humidity, and wind speed, this index is particularly effective for determining the thermal comfort of people in hot and humid areas. THI and K-index are widely used in biometeorology and meteorology to represent human thermal comfort and quantify the combined influence of meteorological variables. In this study, a significant positive correlation was found between K and COVID-19. The results of the study suggest that there is a negative correlation between daily confirmed COVID-19 cases and temperature, humidity, wind speed, rainfall, and THI, but Index of wind effect is associated with an increase in daily confirmed COVID-19 cases. Environmental variables may play a role in the transmission of COVID-19 and should be considered when developing public health interventions in Selangor, Malaysia, according to the results of this study.

The Malaysian government and the Ministry of Health (MOH) have implemented various strategies to reduce the transmission of COVID-19 in Malaysia. The government has implemented several phases of MCO, which restrict the movement of people and limit the gathering of individuals to control the spread of COVID-19. The government has also implemented strict border control measures to limit the entry of COVID-19 cases into Malaysia. This includes mandatory quarantine and testing for all international travellers. The MOH has conducted extensive contact tracing to identify and isolate individuals who have been in contact with COVID-19 patients.

In terms of healthcare capacity, the government has increased the healthcare capacity by setting up additional hospitals and quarantine centres, as well as recruiting more healthcare workers to handle the increasing number of COVID-19 cases. The government has launched various public education campaigns to promote awareness of COVID-19 and the importance of following preventive measures such as wearing masks, social distancing, and washing hands regularly. Finally, the government has launched a national vaccination program to vaccinate the population against COVID-19. The vaccination program is being carried out in phases, with priority given to high-risk groups such as healthcare workers, the elderly, and individuals with comorbidities.

Overall, the Malaysian government and MOH have implemented a comprehensive set of strategies to reduce the transmission of COVID-19 in Malaysia. These measures have helped to control the spread of the virus and reduce the number of cases in the country.

Conclusion

A generalised additive model (GAM) was employed in this work to evaluate the relationship between daily confirmed COVID-19 cases and a variety of environmental parameters such as temperature, humidity, wind speed, rainfall, and temperature humidity index (THI). The analysis found a strong inverse association between daily verified COVID-19 instances and temperature, humidity, wind speed, rainfall, and THI. In addition, the investigation revealed that temperature humidity index was significantly related to an increase in daily COVID-19 cases.

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Competing interests

The authors declare that they have no competing interests.

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