ILKOM Jurnal Ilmiah Vol. 13, No. 3, December 2021, pp. 195-205
Accredited 2nd by RISTEKBRIN No. 200/M/KPT/2020; E-ISSN 2548-7779 | P-ISSN 2087-1716

Research Article Open Access (CC–BY-SA)

A correlation method for meteorological factors and air pollution in association to Covid-19 pandemic in the most affected city in Indonesia

Nurilmiyanti Wardhani[a,1], Hamdan Gani[b,2], Sitti Zuhriyah[a,3,*],Helmy Gani[c,4], Etika Vidyarini[d,5]
[a]*Department of Informatics Engineering, STMIK Handayani, Makassar, Indonesia*
[b]*Graduate School of Computer System, STMIK Handayani, Makassar, Indonesia*
[c]*Department of Industrial Hygiene and Occupational Health, Akademi Hiperkes Makassar, Makassar, Indonesia*
[d]*Department of Interior Design, Institut Teknologi Bandung, Bandung, Indonesia*
[1]*nurilmiyanti@handayani.ac.id;* [2] *hamdangani@handayani.ac.id;* [3] *zuhriyah@handayani.ac.id;* [3] *helmy.gani@mail.com;*
[5]*etika.vidyarini@gmail.com*
** Corresponding author*

Article history: Received May 05, 2021; Revised July 25, 2021; Accepted July 26, 2021; Available online August 08, 2021

Abstract

This study aims to validate the correlation between meteorological factors and air pollution with the spread of Covid-19 in Jakarta, Indonesia. This study examined the Covid-19 cases of Jakarta and its five municipalities. The secondary data of Covid-19 cases, includes Daily Positive Cases (DPC) and Total Daily Positive Cases (TDPC), were retrieved from the Health Office of DKI Jakarta Province, while the meteorological and air pollution parameters were obtained from the online database archives. Kendall and Spearman rank correlation tests were used to analyze correlation between DPC and TDPC with meteorological and air pollution parameters. This study found that Air Quality Index and PM10 showed a significant positive correlation with DPC in municipalities of Jakarta. Also, the average air temperature was positively correlated to TDPC in all region of Jakarta. Average air temperature, Air Quality Index, and PM10 were the factors that take into account for the spread of Covid-19 pandemic in Jakarta, Indonesia. The warmer temperature associated to the higher number of cases. Thus, there are no indications that the spread of Covid-19 in subtropical or temperate country may decrease when entering a warmer season that resembles the climatic characteristics in tropical region. Additionally, the significance of air pollutant factors implies that reducing air pollution should be promoted as it might reduce the spread of Covid-19. The findings of this study would be useful to support the strategy and policy in preventing the spread of Covid-19 in the country.

Keywords: Covid-19; Meteorological Factors; Air Pollution; Tropical Climate; Indonesia.

Introduction

At the end of 2019, China's government reported an outbreak of a novel coronavirus. The new type of pneumonia disease was named coronavirus or 2019 novel coronavirus (2019-nCov) [1], [2]. The International Committee on Taxonomy of Viruses (ICTV) named the virus SARS-CoV-2 and the disease as Covid-19 [3]. The rapid spread of this respiratory disease has led the WHO to declare a global pandemic [4].

The researchers have shown that temperature and humidity are significant factors in the transmission of respiratory diseases such as middle east respiratory syndrome coronavirus (MERS-Cov) [5] and severe acute respiratory coronavirus (SARS-Cov) [6]. Some studies identified that pneumonia and influenza's transmission are influenced by climate factors [7]–[9]. SARS-Cov-2 can be viable in aerosols for an hour [10]. Meteorological factors are commonly believed to influence the transmission of coronavirus [11]–[14].

The recent studies have explored the effects of meteorological factors on the spread of Covid-19 across different worlds such as the USA [15], [16], Iran [17], Spain [18], Norway [19], Turkey [20], China [21]–[27], and around the world [28]–[32]. However, there is still arguable whether the spread of Covid-19 is affected by the meteorological factors [27], [33]–[36]. Yao et al. [35] reported no association between Covid-19 transmission with temperature in China. Another study estimated that climate factors only 18% influenced the spread of the disease, and the remaining 82% may be associated with general public health policy, population density, cultural factors, and transportation [21]. Apart from the controversial findings, the results of previous works that have been done during the winter season might not be sufficient for tropical areas. Those studies predicted that numbers of Covid-19 cases will decrease as the temperature gets warm. Up to now, the current paper identified that only limited studies investigated the influence of meteorological parameters on Covid-19 transmission in tropical areas such as Brazil [37], [38], Mexico [39], Singapore [40], and Indonesia [41], [42]. Therefore, more studies are needed to show the characteristic of Covid-19

http://dx.doi.org/10.33096/ilkom.v13i3.854.195-205

transmission in a tropical country. The other factors, such as air quality and particulate matter, are commonly believed to influence the spread of Covid-19. There is significant evidence that shows the correlation between air quality and Covid-19 cases in China [23]. Several studies have also reported that there was a correlation between air pollutants with the Covid-19 infection [23], [43]–[46]. Uncertainties go on concerning the influence of air pollution and the roles that they play on Covid-19. Specifically, little is known in Indonesia. To the best of our knowledge, a study involving air pollution related to the numbers of Covid-19 cases in Indonesia has not been done. As we know, Jakarta had poor air quality and pollution for many years (https://www.iqair.com/world-most-polluted-cities). Thus, it is interesting to study the effect of air pollution on the spread of Covid-19.

On 2 March 2020, the first case of Covid-19 is announced by Indonesia's government in Jakarta, Indonesia [47], and the number of cases rapidly increase. As of 17 June 2020, a total of 41.431 cases were confirmed in Indonesia, with total deaths of 2.276. Indonesia currently has the highest Covid-19 mortality rate in Asia (https://coronavirus.jhu.edu/), and Jakarta had the most affected city in Indonesia [48]. As Covid-19 spreads on, researchers investigate its characteristics from every possible angle, including the parameters that can minimize the spread of the disease. Despite that, the study about the influence of environmental variables on Covid-19 spread is still limited in Indonesia. Currently, only two studies investigated the influence of climate variables on Covid-19 in Indonesia [41], [42]. Furthermore, the World Health Organization (WHO) states that more studies are required to get new insight regarding the characteristics of the Covid-19 pandemic. Thus, studying meteorological parameters and air pollution in the more recent observation time will be beneficial for the current understanding related to the Covid-19 in the central pandemic city of Indonesia.

Our study aims to validate the correlation between meteorological factors and air pollution with the spread of Covid-19 in Jakarta, Indonesia. The previous works had investigated the correlation between climate parameters and Covid-19 cases in Jakarta from January to 10 April 2020 [41], [42]. Our study extends those works to find any significant correlation between meteorological parameters and air pollutants with the spread of Covid-19, from 25 March 2020 to 31 May 2020. It extended the study period as well as air pollutant parameters to get a new understanding regarding Covid-19. The results of this study can provide scientific evidence about the conditions of Covid-19.

Method

A. Study area

Jakarta, the capital city of Indonesia, lies off the Java island in the maritime of southeast Asia. It covers approximately an area of 662.33 km2. It was owing to its geographical location (60 12' South latitude and 1060 48' East longitude). Jakarta has 11.063.324, with a population density of 16.704 people per km2 [49]. Koppen's climate classification for Jakarta is a tropical climate (tropical monsoon climate). Climate data recorded during 2005-2015 indicate that the hottest month is October with an average air temperature of 30 0C, and the coldest month is February, with an average air temperature of 28 0C. The wettest month is February, with an average precipitation of 199.8 mm and annual precipitation of 1178.5 mm per year [50]. Jakarta consists of six municipalities or zone. The municipalities of Jakarta are Central Jakarta, West Jakarta, East Jakarta, South Jakarta, North Jakarta, and Thousand Islands. The Thousand Islands is a chain of islands to the north of Jakarta's coast located outside Java island. Thousand Island was excluded from this study because the air pollutant data was not covered. **Table 1** shows the total population and population density of five municipalities in Jakarta.

Table 1. Population in Jakarta and its five municipalities in the year 2015

Municipalities	Area (km^2)	Total population	Population density (people per km^2)
Jakarta	662.33	11.063.324	16.704
East Jakarta	188.03	2,817,994	14,987
West Jakarta	129.54	2,430,410	18,762
South Jakarta	141.27	2,164,070	15,319
North Jakarta	146.66	1,729,444	11,792
Central Jakarta	48.13	910,381	18,915

*Data were obtained from http://data.jakarta.go.id/

B. Covid-19 positive cases and meteorological data

Secondary data on positive cases were obtained from the Health Office of DKI Jakarta Province (https://corona.jakarta.go.id/). The data was obtained from 25 March until 31 May 2020 (N = 68 observation days). This study analyzed both of the numbers Daily Positive Case (DPC) and Total Daily Positive Case (TDPC) of Covid-19. DPC is a number of positive cases that occurred each day, while TDPC presents the total daily positive case that occurred from the first observation day. TDPC is obtained by adding the numbers of DPC. The components of weather include maximum temperature (Tmax), average temperature (Tavg), minimum temperature (Tmin), average humidity (Havg), amount of rainfall (Prec), average wind speed (WSavg), maximum wind speed (WSmax). Tmax, Tavg, Tmin,

Havg, Prec, WSavg, and WSmax were collected from the Meteorological, Climatological, and Geophysical Agency (https://www.bmkg.go.id/). The Air Quality Index (AQI) was collected from Air Metter, a global air quality service provider (https://air-quality.com/). The particulate matter, PM2.5, and PM10 were obtained from the World Air Quality Index (https://aqicn.org/). The Air Quality Index level explained the levels of six monitored atmospheric pollutants. The Air Quality Index level shows how clear or polluted the air is. For instance, an air quality index level of 0 to 50 implies good air quality with a low possibility of affecting public health. As the Air Quality Index level increase, they indicate the more severe health concerns (51-100: moderate; 101-150: unhealthy for sensitive groups; 151-200: unhealthy, 201-300: very unhealthy; >300: hazardous) [51]. Particulates matter (PM10 and PM2.5) is complex air pollution and shows how clean or polluted the air [52].

C. Statistical methods

The parametric test was not fulfilled (Kolmogorov-Smirnov test of normality (N = 68), $p < 0.001$). Thus, a non-parametric correlation test (Spearman and Kendall rank correlation test) was used to analyze the association between environmental parameters with the Covid-19 cases. The bivariate, two-tailed analysis at 95% confidence value was used. Spearman rank correlation coefficient or Spearman's Rho (rs) can be calculated as follows:

$$r_s = 1 - 6 \times \frac{\sum d_i^2}{n(n^2-1)} \quad (1)$$

Where di describes the difference between the ranks of two parameters and n describes the number of available alternatives. The value of rs was either +1 (i.e., perfect positive correlation) or -1 (i.e., perfect negative correlation, respectively.

On the other, Kendall rank correlation or Kendall's tau (τ), is utilized to calculate the ordinal correlation or similarity between two variables. This method can be calculated as follows:

$$\tau = \frac{[(concor)-(discor)]}{0.5 \times n \times (n-1)} \quad (2)$$

Where *concor* and *discor* describe the number of concordant and discordant sets, respectively, the *n* describes the number of sets. The value of τ ranges from −1 to +1 and has a related explanation as Spearman's correlation. In this paper, XLSTAT software was used (https://www.xlstat.com/) to execute the above-stated statistical methods.

Results and Discussion

A. Covid-19 positive cases and environmental parameters

Within the observation period of 25 March 2020 - 31 May 2020, Jakarta had the highest number of Covid-19 cases in Indonesia, with a total of 7.272 positive cases and total deaths 520, respectively [48]. Despite the enforcement of large-scale social restrictions (partial lockdown) from 10 April to 4 June 2020 [53], data presented an increase of Covid-19 cases (**Fig. 1, Fig. 2, and Table 2**). During the study period, the temperature was recorded as high as 35.2 °C and as low as 29.6 °C. The average humidity was recorded as high as 86% and as low as 68%. The lowest rainfall was 0 mm, and the highest was 57.2 mm. The average wind speed was recorded as high as 4 m/s and as low as 1 m/s. In addition, the Air Quality Index was recorded as high as 159 and as low as 66. PM2.5 was recorded as high as 139 and as low as 47, and PM10 was recorded as high as 55 and as low as 15. Daily variations of climate parameters and air pollutants in Jakarta are shown in **Fig. 3a-3e**, and the descriptive statistical analysis is presented in **Table 3**.

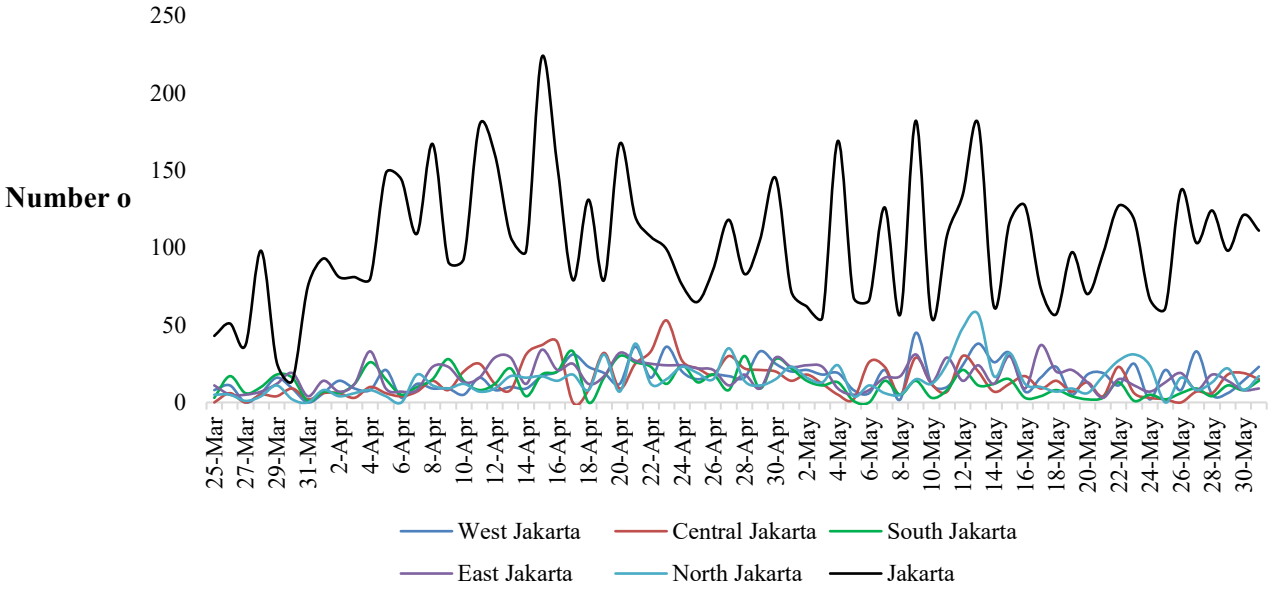

Figure 1. Daily positive cases in Jakarta and five municipalities.

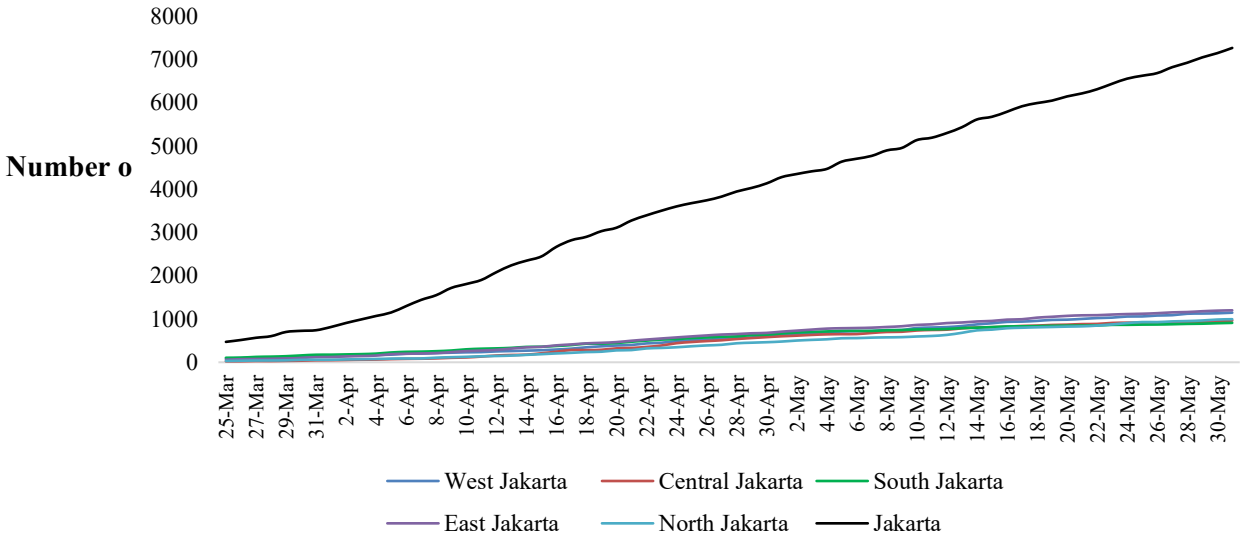

Figure 2. Total Daily positive cases in Jakarta and five municipalities.

Table 2. Total Daily Positive Cases in each observed month in Jakarta and its five municipalities.

	March (N = 31)	**April (N = 30)**	**May (N = 31)**
Jakarta	741	4138	7272
East Jakarta	118	679	1202
West Jakarta	139	607	1147
North Jakarta	58	464	996
Central Jakarta	45	581	965
South Jakarta	174	638	911

Table 3. Descriptive statistical analysis of environmental parameters in Jakarta (25 March - 31 May 2020)

		Min	**Max**	**Mean**	**SD**	**Median**	**Mode**	**Kurtosis**	**Skewness**
Meteorological parameters	T_{max} (°C)	29.6	35.2	32.5	1.1	32.5	32.2	0.1	-0.2
	T_{avg} (°C)	27.2	31.4	29.3	0.8	29.3	29.9	0.0	-0.1
	T_{min} (°C)	24.8	28.7	26.9	0.8	27.0	27.2	-0.2	-0.4
	H_{avg} (%)	68.0	86.0	78.9	3.2	79.0	80.0	1.0	-0.6
	Prec (mm)	0.0	57.5	2.9	8.8	0.0	0.0	23.2	4.5
	WS_{avg} (m/s)	1.0	4.0	2.3	0.6	2.0	2.0	0.6	0.9
	WS_{max} (m/s)	3.0	8.0	5.1	1.3	5.0	4.0	-0.1	0.6
Air pollutants	AQI	66.0	159.0	112.8	24.5	110.0	88.0	-1.0	0.2
	$PM_{2.5}$	47.0	139.0	93.0	19.1	92.5	68.0	-0.5	-0.1
	PM_{10}	15.0	55.0	38.4	9.3	40.0	44.0	-0.1	-0.5

B. Correlation between Covid-19 positive cases and environmental parameters

Table 4 shows the empirical estimations of the environmental variables with DPC. The correlation test showed the diversity results of Jakarta and its five municipalities. Average wind speed ($p < 0.05$) and PM10 ($p < 0.05$) were positively correlated with DPC in North Jakarta. AQI, PM2.5, and PM10 were positively correlated with DPC ($p < 0.05$), whereas the amount of rainfall ($p < 0.05$) was negatively associated with DPC in South Jakarta. In West Jakarta, only PM10 ($p < 0.05$) was positively correlated with DPC. In East Jakarta, minimum temperature ($p < 0.05$) and PM2.5 ($p < 0.05$) were positively associated and AQI ($p < 0.01$) showed positive significant associations with DPC. PM2.5 ($p < 0.05$), AQI ($p < 0.01$), and PM10 ($p < 0.01$) showed positive significant correlations with DPC in Central Jakarta.

Table 5 indicates the empirical estimations of the environmental parameters with TDPC. Both correlation test presents that the number of TDPC in Jakarta and its five municipalities were positively correlated to the maximum temperature ($p < 0.05$) and average temperature ($p < 0.01$), while negatively associated with average humidity ($p < 0.05$). The average temperature is more influential than other parameters. In contrast, no significant correlation ($p > 0.05$) was found between the number of TDPC to the air pollutant parameters.

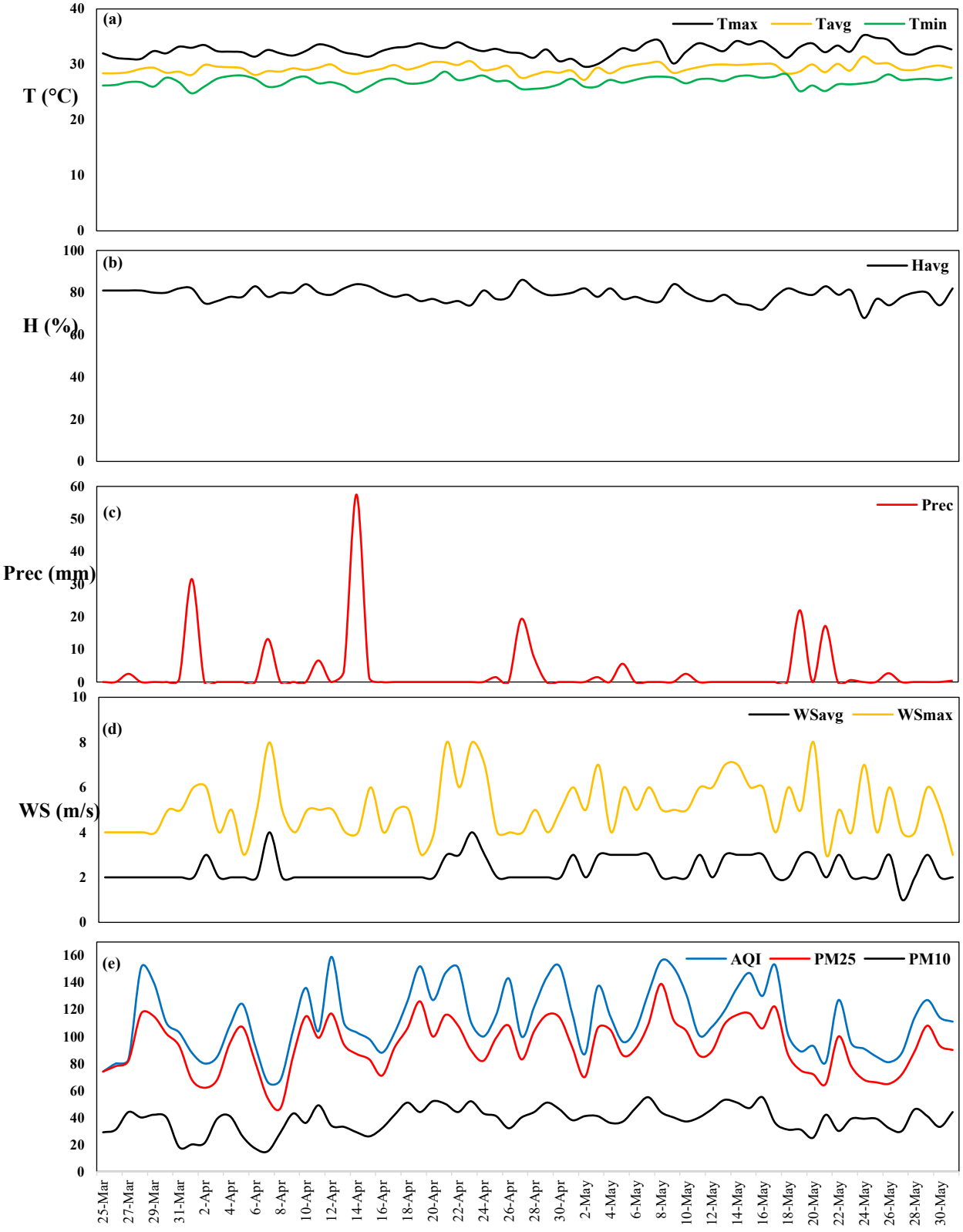

Figure 3. (a) Temperature (°C), (b) Humidity (%), (c) Amount of Rainfall (mm), (d) Wind Speed (m/s), (e) Air Quality Index, $PM_{2.5}$, and PM_{10} over Jakarta from 25 March to 31 May, 2020.

Table 4. Empirical results of Daily Positive Cases (DPC)

			Jakarta	North Jakarta	South Jakarta	West Jakarta	East Jakarta	Central Jakarta
Kendall Correlation Coefficient	Meteorological parameters	T_{max} (°C)	0.044	0.014	-0.165	-0.029	-0.011	-0.014
		T_{avg} (°C)	0.049	0.062	0.011	0.068	0.138	0.042
		T_{min} (°C)	0.052	0.000	0.163	0.084	0.182*	0.021
		H_{avg} (%)	0.021	-0.025	-0.006	-0.090	-0.073	0.015
		Prec (mm)	-0.024	0.061	-0.209*	-0.170	-0.142	-0.056
		WS_{avg} (m/s)	0.044	0.234*	-0.051	0.056	0.075	0.116
		WS_{max} (m/s)	0.016	0.149	-0.001	0.042	0.175	0.150
	Air pollutants	AQI	0.095	0.112	0.185*	0.148	0.248**	0.248**
		$PM_{2.5}$	0.058	0.068	0.176*	0.138	0.195*	0.196*
		PM_{10}	0.069	0.204*	0.177*	0.218*	0.156	0.221**
Spearman Correlation Coefficient	Meteorological parameters	T_{max} (°C)	0.070	0.036	-0.229	-0.046	-0.028	-0.028
		T_{avg} (°C)	0.076	0.090	0.014	0.087	0.193	0.049
		T_{min} (°C)	0.077	0.007	0.227	0.132	0.261*	0.034
		H_{avg} (%)	0.022	-0.039	-0.011	-0.116	-0.098	0.026
		Prec (mm)	-0.029	0.079	-0.272*	-0.215	-0.181	-0.070
		WS_{avg} (m/s)	0.056	0.290*	-0.058	0.069	0.091	0.142
		WS_{max} (m/s)	0.025	0.199	-0.007	0.069	0.228	0.195
	Air pollutants	AQI	0.133	0.172	0.289*	0.208	0.362**	0.367**
		$PM_{2.5}$	0.088	0.112	0.272*	0.187	0.293*	0.298*
		PM_{10}	0.096	0.285*	0.238	0.302*	0.229	0.321**

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Table 5. Empirical results of total daily positive cases (TDPC).

			Jakarta	North Jakarta	South Jakarta	West Jakarta	East Jakarta	Central Jakarta
Kendall Correlation Coefficient	Meteorological parameters	T_{max} (°C)	0.200*	0.201*	0.198*	0.201*	0.200*	0.203*
		T_{avg} (°C)	0.241**	0.242**	0.239**	0.241**	.241**	0.244**
		T_{min} (°C)	0.146	0.146	0.144	0.147	0.146	0.146
		H_{avg} (%)	-0.182*	-0.181*	-0.179*	-0.182*	-0.182*	-0.186*
		Prec (mm)	-0.027	-0.029	-0.025	-0.026	-0.027	-0.024
		WS_{avg} (m/s)	0.189	0.187	0.189	0.189	0.189	0.193
		WS_{max} (m/s)	0.136	0.134	0.136	0.136	0.136	0.138
	Air pollutants	AQI	0.072	0.074	0.07	0.072	0.072	0.069
		$PM_{2.5}$	0.014	0.015	0.011	0.013	0.014	0.009
		PM_{10}	0.114	0.113	0.113	0.114	0.114	0.114
Spearman	Meteorological parameters	T_{max} (°C)	0.304*	0.303*	0.302*	0.304*	0.304*	0.309*

			Jakarta	North Jakarta	South Jakarta	West Jakarta	East Jakarta	Central Jakarta
		T_{avg} (°C)	0.335**	0.335**	0.333**	0.334**	0.335**	0.339**
		T_{min} (°C)	0.194	0.194	0.192	0.195	0.194	0.195
		H_{avg} (%)	-0.255*	-0.254*	-0.253*	-0.255*	-0.255*	-0.257*
		Prec (mm)	-0.033	-0.035	-0.031	-0.031	-0.033	-0.03
		WS_{avg} (m/s)	0.233	0.231	0.233	0.233	0.233	0.238
		WS_{max} (m/s)	0.172	0.17	0.173	0.172	0.172	0.176
	Air pollutants	AQI	0.124	0.124	0.121	0.122	0.124	0.121
		$PM_{2.5}$	0.015	0.015	0.012	0.013	0.015	0.012
		PM_{10}	0.176	0.175	0.174	0.176	0.176	0.176

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

C. Discussion

Based on DPC results, the current study estimates that minimum temperature (average: 26.9 °C) showed positive associations with DPC of Covid-19. A previous study by Pani et al. [40] supports our findings. However, the correlation of minimum temperature was not found in Jakarta by the previous study of Tosepu [41]. For average wind speed (average: 2.3 m/s), our study identified positive associations with DPC. Similar to our study, a positive correlation was also reported over Oslo, Norway [19], New York, the USA [16], and Turkey [20]. Conversely, a negative association was found between Iran [17] and Singapore [40]. Furthermore, unlike the previous work that did not correlate rainfall and Covid-19 cases in Jakarta [41], our study found negative associations (average: 2.9 mm) with DPC. Similarly, the negative correlations were also reported over New York [16] and Oslo [19]. In addition, our study found that PM2.5 (average: 93) showed a positive association with the DPC. Likewise, previous studies observed similar findings in China [43] and California [44]. PM10 (average: 38.4) and AQI (average: 112.8) was also showed significant positive correlations with DPC. That findings confirm previous results in China [23], [43], [54].

Our findings estimate that the average temperature (average: 29.3 °C) was significantly correlated with the TDPC of Covid-19 in all Jakarta areas, which is supported by the previous evidence (the lowest average temperature: 26.1 °C and the highest: 28.6 °C) in Jakarta as well [41]. Moreover, in Singapore, Pani et al. [40] revealed that maximum temperature (average: 32 °C) was strongly associated with Covid-19 cases during the early transmission phase. Our findings are consistent with the previous results (average: 32.5 °C). Meanwhile, Tosepu et al. [41] were not found any correlation in Jakarta. Additionally, average relative humidity (near 80 %) were also played a significant role in the transmission rate of Covid-19 in Brazil [38]. However, our results are different since we observed a negative relationship between the average humidity (average: 78.9%) with Covid-19 cases.

Overall, the warmer the air temperature, the higher the number of cases is. It shows that climate parameters might be a significant factor for the number of Covid-19 cases in Jakarta and its five municipalities. Interestingly, the spread of the disease and the correlation towards meteorological parameters are relatively distributed for all municipalities in Jakarta (Table 5). It would seem that the spread of Covid-19 was more tolerant of warmer air temperature (maximum, minimum, and average temperature), which is also supported by previous findings (Appendix A). Interestingly, our results contradict the findings of previous studies in the cold temperatures countries (Appendix B). Liu et al. [25] reported that the epidemic might gradually ease partially due to rising temperatures in the coming months in China. Shi et al. [22] reported that the incidence of Covid-19 decreases with the increase of temperature in China. Wang et al. [55] observed that high temperatures and high relative humidity significantly reduce the spread of Covid-19 in China.

In this case, those previous findings could not be implemented in a tropical area, which has average air temperature ranged from 25-33 °C and humidity ranging from 60-80%, which is relatively constant throughout the year. Furthermore, the abovementioned previous works were early studies that investigated the spread of Covid-19 in the winter season in China (January-February 2020), and the spread of Covid-19 was not globally reached in the tropical country. Thus, the characteristics of the Covid-19 pandemic are not seen in tropical countries. In fact, in the coming summer season from June to mid-October, the temperatures are reached at an average between 26 °C and 33 °C [56]. The number of Covid-19 cases is still increasing in a tropical countries, such as Indonesia (https://coronavirus.jhu.edu/). Thus, it could be inferred that the spread of Covid-19 in the subtropical or temperate country may not decrease when entering a warmer season that resembles the climatic characteristics (including the maximum, minimum, and average air temperature) in the tropical region. This speculation is in line with the previous findings [18], [37], [38], [40], [41]. The decreased numbers of cases reported in previous studies in the cold temperatures countries (Appendix B) might be influenced by other policies, such as social distancing.

Other interesting findings were found that the components of air pollutants, AQI and PM10, showed a significant positive correlation with DPC in Central Jakarta. Central Jakarta is the smallest in area, but it is the most densely populated compared to other municipalities in Jakarta (Table 1). As a center of the city's administrations and businesses, Central Jakarta has several industrial sectors and oversees high mobility where people work in and around the region (https://jakarta.go.id/infografis). Consequently, air pollutions in Central Jakarta might be higher than in other municipalities. Therefore, reducing air pollutants and limited people's exposure to pollutants might contribute to minimizing the transmission of Covid-19. Previous works also support this claim that the region with a high air pollution concentration might suffer a severe Covid-19 pandemic [43], [54]. Despite the positive findings, assessing the effect of short-term air pollution on the spread of Covid-19 are still debatable. Short-term exposure might not imply the vulnerability of the population to Covid-19. The more extended period of exposure, multiple pollutants, the spatial distribution of particulate matter concentration are needed to explore to answer the issues the effect of air pollution on the transmission of Covid-19 as mentioned by [57]. Further investigation is needed to validate the sources of that relationship.

Despite the environmental factors, the increase of Covid-19 cases in Jakarta is also affected by the population density. Jakarta's population density is very high compared to other cities in Indonesia. Jakarta is the center of commercial and business to seek employment and business opportunities where people come from different areas in Indonesia. This condition affects the very high mobility of the people and triggers Covid-19 transmission to be very fast [58]. Previous studies of [59] and [60] have shown evidence that community mobility significantly influenced the spread of Covid-19 in China and the USA. In the case of Jakarta, despite the implementation of partial lockdown from 10 April to 4 June 2020, Covid-19 cases were still increasing (Fig. 1 and Fig. 2). The reason is that the enforcement of rules was not effective [61]. Outside activities and disobedience of regulations are still occurring during the implementation of partial lockdown [62], and industrial factories could continue their business if they obtain a permit from Industrial Ministry and strictly apply health procedures [63].

Although showing a strong association between environmental parameters and the Covid-19 pandemic in Jakarta, this study has the following limitations. First, the spread of Covid-19 is influenced by many parameters, such as population density [14], social distancing [64], [65], and population mobility [59], [60]. Second, individual factors, such as age [66], people's endurance [67], [68], community consciousness [64], and handwashing habits [69], have also played a significant part in the transmission of Covid-19. Third, other environmental parameters, such as relative humidity, absolute humidity, water vapor, boundary layer height, ventilation coefficient, sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), and ozone (O3) are needed to explore. Fourth, our data did not include subgroup analysis, such as gender and age. Fifth, the findings of our study are an estimation and are not globally representative of the condition of Covid-19 transmission in Indonesia. Sixth, the correlation test does not indicate substantial causation without considering any other factor probably verifying the spread of Covid-19, besides climate factors and air pollution. Finally, investigating the effect of long-term exposure of environmental variables (more extended study period) on Covid-19 transmission is needed before we arrive at a definite conclusion.

Conclusion

This study aims to validate the correlation between meteorological factors and air pollution with the spread of the Covid-19 in Jakarta, Indonesia. This study finds that air temperature (minimum, maximum, and average air temperature), average wind speed, Air Quality Index, PM10, and PM2.5 are significantly correlated with Covid-19. The association of average temperature, air quality index, and PM10 with Covid-19 cases are more influential than other parameters. There are no suggestions that the spread of Covid-19 may decrease at maximum, minimum, and average temperature temperatures in the tropical region. Additionally, the findings of this study imply that reducing air pollutions or a green environment should be promoted as it might reduce the spread of infectious diseases such as Covid-19. The local government should pay more attention to regions with a high concentration of air pollution and awareness regarding the spread of Covid-19 that may not decrease at the tropical climate temperatures. Our findings could be considered as a material consideration in the decision-making in preventing the spread of Covid-19. Future research should conduct comprehensive studies using more environmental parameters and other possible factors. Also, various data from meteorological stations across the island are needed to better understand the conditions of Covid-19 in Indonesia.

Acknowledgment

We gratefully thank the Health Office of DKI Jakarta Province, the Meteorological, Climatological, and Geophysical Agency, The World Air Quality Index project, and Air Matters for providing the information on their webpage. The authors also acknowledge that this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] M. A. Shereen, S. Khan, A. Kazmi, N. Bashir, and R. Siddique, "COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses," *Journal of Advanced Research*, vol. 24, pp. 91–98, 2020, doi: 10.1016/j.jare.2020.03.005.

[2] Y. Chen, Q. Liu, and D. Guo, "Emerging coronaviruses: Genome structure, replication, and pathogenesis," *Journal of Medical Virology*, vol. 92, no. 4, pp. 418–423, Apr. 2020, doi: 10.1002/jmv.25681.

[3] C. C. Lai, T. P. Shih, W. C. Ko, H. J. Tang, and P. R. Hsueh, "Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges," *International Journal of Antimicrobial Agents*, vol. 55, no. 3, p. 105924, 2020, doi: 10.1016/j.ijantimicag.2020.105924.

[4] WHO, "Coronavirus disease 2019 (COVID-19) situation report – 41. Retrieved from.," 2020. https://www.who.int/docs/default-source/coronaviruse/situation-reports/%0A20200301-sitrep-41-covid-19.pdf?sfvrsn=6768306d_2. (accessed Jul. 14, 2020).

[5] A. Altamimi and A. E. Ahmed, "Climate factors and incidence of Middle East respiratory syndrome coronavirus," *Journal of Infection and Public Health*, vol. 13, no. 5, pp. 704–708, 2020, doi: 10.1016/j.jiph.2019.11.011.

[6] Q. C. Cai *et al.*, "Influence of meteorological factors and air pollution on the outbreak of severe acute respiratory syndrome," *Public Health*, vol. 121, no. 4, pp. 258–265, 2007, doi: 10.1016/j.puhe.2006.09.023.

[7] A. I. Barreca, "Climate change, humidity, and mortality in the United States," *Journal of Environmental Economics and Management*, vol. 63, no. 1, pp. 19–34, Jan. 2012, doi: 10.1016/j.jeem.2011.07.004.

[8] A. I. Barreca and J. P. Shimshack, "Absolute humidity, temperature, and influenza mortality: 30 years of county-level evidence from the united states," *American Journal of Epidemiology*, vol. 176, no. SUPPL. 7, pp. S114–S122, 2012, doi: 10.1093/aje/kws259.

[9] R. E. Davis, E. Dougherty, C. McArthur, Q. S. Huang, and M. G. Baker, "Cold, dry air is associated with influenza and pneumonia mortality in Auckland, New Zealand," *Influenza and other Respiratory Viruses*, vol. 10, no. 4, pp. 310–313, 2016, doi: 10.1111/irv.12369.

[10] N. Van Doremalen *et al.*, "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1," *New England Journal of Medicine*, vol. 382, no. 16, pp. 1564–1567, 2020.

[11] L. M. Casanova, S. Jeon, W. A. Rutala, D. J. Weber, and M. D. Sobsey, "Effects of air temperature and relative humidity on coronavirus survival on surfaces," *Applied and Environmental Microbiology*, vol. 76, no. 9, pp. 2712–2717, 2010, doi: 10.1128/AEM.02291-09.

[12] N. Pica and N. M. Bouvier, "Environmental factors affecting the transmission of respiratory viruses," *Current Opinion in Virology*, vol. 2, no. 1, pp. 90–95, 2012, doi: 10.1016/j.coviro.2011.12.003.

[13] J. S. Kutter, M. I. Spronken, P. L. Fraaij, R. A. Fouchier, and S. Herfst, "Transmission routes of respiratory viruses among humans," *Current Opinion in Virology*, vol. 28, pp. 142–151, 2018, doi: 10.1016/j.coviro.2018.01.001.

[14] K. H. Chan, J. S. M. Peiris, S. Y. Lam, L. L. M. Poon, K. Y. Yuen, and W. H. Seto, "The effects of temperature and relative humidity on the viability of the SARS coronavirus," *Advances in Virology*, vol. 2011, 2011, doi: 10.1155/2011/734690.

[15] S. Gupta, G. S. Raghuwanshi, and A. Chanda, "Effect of weather on COVID-19 spread in the US: A prediction model for India in 2020," *Science of the Total Environment*, vol. 728, p. 138860, 2020, doi: 10.1016/j.scitotenv.2020.138860.

[16] M. F. Bashir *et al.*, "Correlation between climate indicators and COVID-19 pandemic in New York, USA," *Science of the Total Environment*, vol. 728, p. 138835, 2020, doi: 10.1016/j.scitotenv.2020.138835.

[17] M. Ahmadi, A. Sharifi, S. Dorosti, S. Jafarzadeh Ghoushchi, and N. Ghanbari, "Investigation of effective climatology parameters on COVID-19 outbreak in Iran," *Science of the Total Environment*, vol. 729, p. 138705, 2020, doi: 10.1016/j.scitotenv.2020.138705.

[18] Á. Briz-Redón and Á. Serrano-Aroca, "A spatio-temporal analysis for exploring the effect of temperature on COVID-19 early evolution in Spain," *Science of the Total Environment*, vol. 728, p. 138811, 2020, doi: 10.1016/j.scitotenv.2020.138811.

[19] M. M. Menebo, "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*, vol. 737, p. 139659, 2020, doi: 10.1016/j.scitotenv.2020.139659.

[20] M. Şahin, "Impact of weather on COVID-19 pandemic in Turkey," *Science of the Total Environment*, vol. 728, p. 138810, 2020, doi: 10.1016/j.scitotenv.2020.138810.

[21] B. Oliveiros, L. Caramelo, N. C. Ferreira, and F. Caramelo, "Role of temperature and humidity in the modulation of the doubling time of COVID-19 cases," *medRxiv*, p. 2020.03.05.20031872, 2020, doi: 10.1101/2020.03.05.20031872.

[22] P. Shi *et al.*, "Impact of temperature on the dynamics of the COVID-19 outbreak in China," *Science of the Total Environment*, vol. 728, p. 138890, 2020, doi: 10.1016/j.scitotenv.2020.138890.

[23] H. Xu *et al.*, "Possible environmental effects on the spread of COVID-19 in China," *Science of the Total Environment*, vol. 731, p. 139211, 2020, doi: 10.1016/j.scitotenv.2020.139211.

[24] H. Qi *et al.*, "COVID-19 transmission in Mainland China is associated with temperature and humidity: A time-series analysis," *Science of the Total Environment*, vol. 728, p. 138778, 2020, doi:

10.1016/j.scitotenv.2020.138778.
[25] J. Liu *et al.*, "Impact of meteorological factors on the COVID-19 transmission: A multi-city study in China," *Science of the Total Environment*, vol. 726, p. 138513, 2020, doi: 10.1016/j.scitotenv.2020.138513.
[26] Y. Ma *et al.*, "Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China," *Science of the Total Environment*, vol. 724, p. 138226, 2020, doi: 10.1016/j.scitotenv.2020.138226.
[27] J. Xie and Y. Zhu, "Association between ambient temperature and COVID-19 infection in 122 cities from China," *Science of the Total Environment*, vol. 724, p. 138201, 2020, doi: 10.1016/j.scitotenv.2020.138201.
[28] W. Luo *et al.*, "The role of absolute humidity on transmission rates of the COVID-19 outbreak," *medRxiv*, p. 7, 2020, doi: 10.1101/2020.02.12.20022467.
[29] M. Wang *et al.*, "Temperature significant change COVID-19 Transmission in 429 cities," *medRxiv*, p. 2020.02.22.20025791, 2020, doi: 10.1101/2020.02.22.20025791.
[30] Y. Wu *et al.*, "Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries," *Science of the Total Environment*, vol. 729, p. 139051, 2020, doi: 10.1016/j.scitotenv.2020.139051.
[31] M. F. F. Sobral, G. B. Duarte, A. I. G. da Penha Sobral, M. L. M. Marinho, and A. de Souza Melo, "Association between climate variables and global transmission oF SARS-CoV-2," *Science of the Total Environment*, vol. 729, p. 138997, 2020, doi: 10.1016/j.scitotenv.2020.138997.
[32] M. M. Sajadi, P. Habibzadeh, A. Vintzileos, S. Shokouhi, F. Miralles-Wilhelm, and A. Amoroso, "Temperature and Latitude Analysis to Predict Potential Spread and Seasonality for COVID-19," *SSRN Electronic Journal*, 2020, doi: 10.2139/ssrn.3550308.
[33] B. Steinfeld *et al.*, "The Role of Lean Process Improvement in Implementation of Evidence-Based Practices in Behavioral Health Care," *Journal of Behavioral Health Services and Research*, vol. 42, no. 4, pp. 504–518, 2015, doi: 10.1007/s11414-013-9386-3.
[34] A. Tobías and T. Molina, "Is temperature reducing the transmission of COVID-19 ?," *Environmental Research*, vol. 186, p. 109553, 2020, doi: 10.1016/j.envres.2020.109553.
[35] Y. Yao *et al.*, "No association of COVID-19 transmission with temperature or UV radiation in Chinese cities," *European Respiratory Journal*, vol. 55, no. 5, 2020, doi: 10.1183/13993003.00517-2020.
[36] S. S. Gunthe, B. Swain, S. S. Patra, and A. Amte, "On the global trends and spread of the COVID-19 outbreak: preliminary assessment of the potential relation between location-specific temperature and UV index," *Journal of Public Health (Germany)*, pp. 1–10, 2020, doi: 10.1007/s10389-020-01279-y.
[37] D. N. Prata, W. Rodrigues, and P. H. Bermejo, "Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil," *Science of the Total Environment*, vol. 729, p. 138862, 2020, doi: 10.1016/j.scitotenv.2020.138862.
[38] A. C. Auler, F. A. M. Cássaro, V. O. da Silva, and L. F. Pires, "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*, vol. 729, p. 139090, 2020, doi: 10.1016/j.scitotenv.2020.139090.
[39] F. Méndez-Arriaga, "The temperature and regional climate effects on communitarian COVID-19 contagion in Mexico throughout phase 1," *Science of the Total Environment*, vol. 735, p. 139560, 2020, doi: 10.1016/j.scitotenv.2020.139560.
[40] S. K. Pani, N. H. Lin, and S. RavindraBabu, "Association of COVID-19 pandemic with meteorological parameters over Singapore," *Science of the Total Environment*, vol. 740, p. 140112, 2020, doi: 10.1016/j.scitotenv.2020.140112.
[41] R. Tosepu *et al.*, "Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia," *Science of the Total Environment*, vol. 725, p. 138436, 2020, doi: 10.1016/j.scitotenv.2020.138436.
[42] A. Asyary and M. Veruswati, "Sunlight exposure increased Covid-19 recovery rates: A study in the central pandemic area of Indonesia," *The Science of the total environment*, vol. 729, p. 139016, 2020, doi: 10.1016/j.scitotenv.2020.139016.
[43] Y. Zhu, J. Xie, F. Huang, and L. Cao, "Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China," *Science of the Total Environment*, vol. 727, p. 138704, 2020, doi: 10.1016/j.scitotenv.2020.138704.
[44] M. F. Bashir *et al.*, "Correlation between environmental pollution indicators and COVID-19 pandemic: A brief study in Californian context," *Environmental Research*, vol. 187, p. 109652, 2020, doi: 10.1016/j.envres.2020.109652.
[45] J. Xie, J. Teng, Y. Fan, R. Xie, and A. Shen, "The short-term effects of air pollutants on hospitalizations for respiratory disease in Hefei, China," *International journal of biometeorology*, vol. 63, no. 3, pp. 315–326, 2019.
[46] B. D. Horne *et al.*, "Short-term elevation of fine particulate matter air pollution and acute lower respiratory infection," *American journal of respiratory and critical care medicine*, vol. 198, no. 6, pp. 759–766, 2018.
[47] CNN Indonesia, "Jokowi Umumkan Dua WNI Positif Corona di Indonesia CNN Indonesia Senin, 02/03/2020

11:36," *CNN Indonesia*, 2020. https://m.cnnindonesia.com/nasional/20200302111534-20-479660/jokowi-umumkan-dua-wni-positif-corona-di-indonesia (accessed May 31, 2020).
[48] Kemkes, "https://covid-monitoring.kemkes.go.id/," 2020. https://covid-monitoring.kemkes.go.id/ (accessed May 31, 2020).
[49] Data.jakarta.go.id, "Data Penduduk DKI Jakarta," 2020. https://data.jakarta.go.id/organization/dinas-kependudukan-dan-catatan-sipil (accessed Jun. 17, 2020).
[50] Timeanddate, "Jakarta weather reports during 2005–2015," 2020. https://www.timeanddate.com/weather/@1642907/climate (accessed Jun. 17, 2020).
[51] Airnow.gov, "Air Quality Index. Retrieved from.," 2020. https://www.airnow.gov/aqi/aqi-basics/#:~:text=Think of the AQI as,300 represents hazardous air quality. (accessed May 31, 2020).
[52] Airnow.gov, "Particulate Matter. Retrieved from.," 2020. https://www.airnow.gov/publications/air-quality-and-your-health/partical-pollution-and-your-health/ (accessed May 31, 2020).
[53] The Jakarta Post, "PSBB. Retrieved from.," 2020. https://www.thejakartapost.com/academia/2020/05/11/in-psbb-we-trust.html.
[54] Y. Yao *et al.*, "Association of particulate matter pollution and case fatality rate of COVID-19 in 49 Chinese cities," *Science of the Total Environment*, vol. 741, p. 140396, 2020, doi: 10.1016/j.scitotenv.2020.140396.
[55] J. Wang, K. Tang, K. Feng, and W. Lv, "High Temperature and High Humidity Reduce the Transmission of COVID-19," *SSRN Electronic Journal*, 2020, doi: 10.2139/ssrn.3551767.
[56] Weather-atlas, "Jakarta climate," 2020. https://www.weather-atlas.com/en/indonesia/jakarta-climate (accessed Jun. 17, 2020).
[57] A. A. Chudnovsky, "Letter to editor regarding Ogen Y 2020 paper: 'Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality,'" *Science of the Total Environment*, no. xxxx, p. 139236, 2020, doi: 10.1016/j.scitotenv.2020.139236.
[58] The Jakarta Post, "Indonesia's climate can limit COVID-19, but high mobility exacerbates it: BMKG," 2020. https://www.thejakartapost.com/news/2020/04/04/indonesias-climate-can-limit-covid-19-but-high-mobility-exacerbates-it-bmkg.html (accessed Jun. 17, 2020).
[59] A. Paez, "Using Google Community Mobility Reports to investigate the incidence of COVID-19 in the United States," *Transport Findings*, pp. 1–8, 2020, doi: 10.32866/001c.12976.
[60] M. U. G. Kraemer *et al.*, "The effect of human mobility and control measures on the COVID-19 epidemic in China," *Science*, vol. 368, no. 6490, pp. 493–497, 2020, doi: 10.1126/science.abb4218.
[61] Tempo, "Covid 19 task force head psbb in jakarta is not effective yet," 2020. https://en.tempo.co/read/1333550/covid-19-task-force-head-psbb-in-jakarta-is-not-effective-yet (accessed Jun. 17, 2020).
[62] Kompas, "Residents still ignoring psbb," 2020. https://kompas.id/baca/english/2020/04/16/residents-still-ignoring-psbb/ (accessed Jun. 17, 2020).
[63] The Jakarta Post, "Ministry allows 11000 companies operate during psbb," 2020. https://www.thejakartapost.com/news/2020/04/22/no-choice-but-to-keep-economy-running-ministry-allows-11000-companies-operate-during-psbb.html (accessed Jun. 17, 2020).
[64] A. Wilder-Smith and D. O. Freedman, "Isolation, quarantine, social distancing and community containment: Pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak," *Journal of Travel Medicine*, vol. 27, no. 2, p. taaa020, 2020, doi: 10.1093/jtm/taaa020.
[65] J. Riou and C. L. Althaus, "Pattern of early human-to-human transmission of Wuhan 2019 novel coronavirus (2019-nCoV), December 2019 to January 2020," *Eurosurveillance*, vol. 25, no. 4, p. 2000058, 2020, doi: 10.2807/1560-7917.ES.2020.25.4.2000058.
[66] Z. Wu and J. M. McGoogan, "Characteristics of and Important Lessons from the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72314 Cases from the Chinese Center for Disease Control and Prevention," *JAMA - Journal of the American Medical Association*, vol. 323, no. 13, pp. 1239–1242, 2020, doi: 10.1001/jama.2020.2648.
[67] WHO, "WHO Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Retrieved from.," World Health Organization, 2020.
[68] B. E. Young *et al.*, "Epidemiologic Features and Clinical Course of Patients Infected with SARS-CoV-2 in Singapore," *JAMA - Journal of the American Medical Association*, vol. 323, no. 15, pp. 1488–1494, 2020, doi: 10.1001/jama.2020.3204.
[69] N. Fishman and D. P. Calfee, "Prevention and Control of Health Care-Associated Infections," *Goldman's Cecil Medicine: Twenty Fourth Edition*, vol. 2, no. 2, pp. 1780–1787, 2011, doi: 10.1016/B978-1-4377-1604-7.00290-6.