Journal of Natural Resources and Environmental Management
11(1): 93-100. http://dx.doi.org/10.29244/jpsl.11.1.93-100
E-ISSN: 2460-5824
http://journal.ipb.ac.id/index.php/jpsl

The relationship between air pollutants and COVID-19 cases and large-scale social restriction's impact on the air quality in Jakarta, Indonesia

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Article Info:
Received: 09 - 02 - 2021
Accepted: 24 - 03 - 2021

Keywords:
Air pollutant, COVID-19, Jakarta, LSSR, Tropospheric NO_2 column

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Abstract. *World Health Organization (WHO) has announced that COVID-19 is a global pandemic and public health emergency. COVID-19 was an infectious disease, and it could remain viable in ambient air for hours. Therefore, this study examines the correlation between air pollutants (PM2.5, PM10, CO, SO_2, NO_2, and O_3) and COVID-19 spread in Jakarta, Indonesia. Also, it evaluates the impact of large-scale social restriction (LSSR) on the air pollution index (API). The air pollutant and COVID-19 data were investigated in three different periods; in 2019, before LSSR, and during LSSR periods. The correlation analysis between air pollutant and COVID-19 cases were analyzed using Spearman correlation test. The study found that the air pollution index of PM2.5, PM10, CO, SO_2, and NO_2 decreased by 9.48%, 15.74%, 29.17%, 6.26%, and 18.34% during LSSR period. While O_3 showed an increase of 4.06%. Another result also found significant positive correlations of SO_2, CO, and PM2.5 with COVID-19 cases. Exposure to SO_2, CO and PM2.5 has driven the area to become vulnerable to COVID-19 infection. Our findings indicated that the relationship between air pollutants and COVID-19 spread could provide a new notion for precaution and control method of COVID-19 outbreak.*

How to cite (CSE Style 8th Edition):
Rendana M, Komariah LN. 2021. The relationship between air pollutants and COVID-19 cases and large-scale social restriction's impact on the air quality in Jakarta, Indonesia. JPSL **11**(1): 93-100. http://dx.doi.org/10.29244/jpsl.11.1.93-100.

INTRODUCTION

The 2019 novel coronavirus disease (COVID-19) is one of the coronaviruses family that announced a public health emergency in 2020 (Shereen *et al.*, 2020). The COVID-19 has firstly appeared in Wuhan city, China, after a resident from that area suffered respiratory infections and pneumonia cases in December 2019 (Sohrabi *et al.*, 2020). A week later, the virus has spread worldwide and caused many cases and deaths. On March 11 2020, World Health Organization (WHO) declared the COVID-19 outbreak as a global pandemic. Until February 2021, the COVID-19 cases had spread in over 100 countries, and total cases and deaths around the world were over 115 million and 2.5 million, respectively (World Health Organization, 2021). In Indonesia, the highest total cases were found in Jakarta, with total cases COVID-19 was 339 735 and the death cases were 5 464 (Ministry of Health Indonesia, 2021). The government has implemented several policies such as social distancing, self-quarantine, and large-scale social restriction (LSSR) to respond to high city cases.

Many studies have been carried out to analyze any prominent factors contributing to the spread of COVID-19. Several studies found that the COVID-19 could transmit through direct contact human-to-human and respiratory droplets (Huang *et al.,* 2020, Li *et al.,* 2020). Also, climate factors are tightly associated with the COVID-19 pandemic (Ma *et al.,* 2020). Furthermore, recent studies investigated the impact of the lockdown phase on air quality (Nakada and Urban, 2020; Tobias *et al.,* 2020). Mahato *et al.* (2020) reported that the concentrations of PM10 and PM2.5 had reduced more than 50% during the lockdown. According to Filonchyk *et al*. (2020), good air quality only occurred in the short term. When fossil fuel combustion at power plants and factories started to operate again, the air quality would decrease again. The concentration of NO_2 and CO had the most significant decrease based on their study.

Previous studies have discussed that ambient air pollutants have an essential role in contributing to the high respiratory infection ratio by making people more vulnerable to the virus (Xie *et al.,* 2019). WHO also reported, annually seven million die because of fine particles in the polluted air condition (Bashir *et al.,* 2020). Because the COVID-19 can remain viable in the air for multiple hours and affects human's respiratory system (Van Doremalen *et al.,* 2020), therefore, air pollutants can be a reliable indicator to identify virus spread. In this study, we aimed to examine the impact of large-scale social restriction (LSSR) on the air pollution index (API) and also investigate the correlation between air pollutants (PM2.5, PM10, SO_2, NO_2, CO, and O_3) and COVID-19 cases in Jakarta, Indonesia.

MATERIALS AND METHODS

Jakarta is the administration, social and political center of Indonesia, with a current population of over 10 million in 2019. It is geographically located between $6^{0}12'$ S and $106^{0}48'$ E (Fig. 1). Jakarta has been an epicenter of the COVID-19 outbreak in Indonesia since it had the highest COVID-19 cases. Daily air pollution index (API) data such as SO_2, NO_2, PM10, PM2.5, CO, and O_3 were obtained from the Department Environment of Jakata, while COVID-19 cases data from the Department Health of Jakarta (publicly available at https://corona.jakarta.go.id). The data were quantitative type and readily in excel dataset. The acquisition date of data for this study was chosen from March 1 to April 30, 2020. To know the impact of quarantine period on air pollution index, this study was divided into two periods of analyses, before large-scale social restriction (LSSR) started from March 25-April 6 2020, and during LSSR began in April 10-April 23, 2020.

Moreover, tropospheric NO_2 concentration over Jakarta was analyzed by OMI on NASA's Aura satellite which was retrieved from NASA's open data portal (https://giovanni.gsfc.nasa.gov/giovanni). The tropospheric NO_2 concentration was evaluated in three different periods, such as in the 2019 year, before, and during LSSR in 2020. The evaluation of NO_2 level from remote sensing data has been widely used in many studies and showed a satisfactory result (Biswal *et al.,* 2020; Silvern *et al.,* 2019). In this study, we would generally obtain a higher reduction of NO_2 from remote sensing data because it covered a large area coverage. It also detected the concentration of pollutants in a column atmosphere. While the ground level of air quality measurement only analyzed the ambient air pollutant concentration in a lower coverage area. In addition, Spearman correlation test was used of analyze the correlation of air pollutants with the COVID-19 cases in the study area. All statistical analyses were analyzed using IBM SPSS Statistics Version 21 (Verma, 2012).

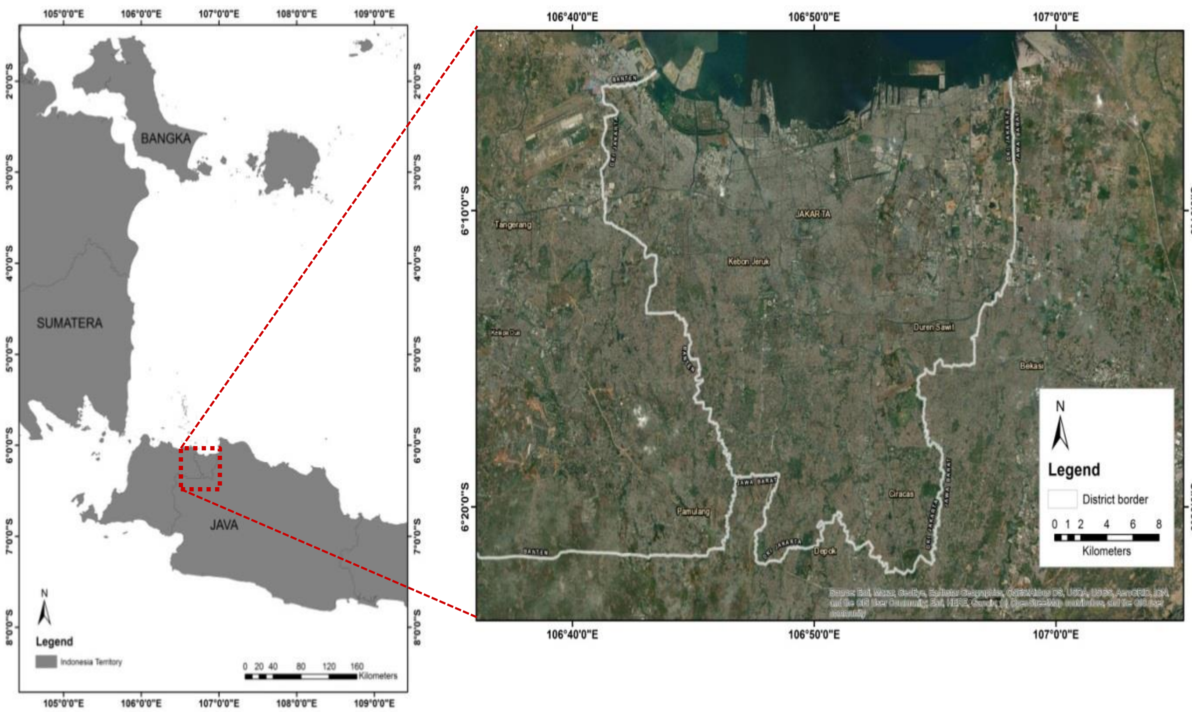

Figure 1 Location of study area

RESULTS AND DISCUSSION

Air Pollution Index (API) in Jakarta during COVID-19 Pandemic

The study's result showed the alteration of the air pollution index in Jakarta using large-scale social restriction (LSSR) to prevent COVID-19 spread. The LSSR from April to June 2020 resulted in a marked reduction in NO_2 in Jakarta by 18.34% (Table 1). This reduction was comparable with the decrease in tropospheric NO_2 columns that also investigated using satellite data (Fig. 2). The reduction in NO_2 could be associated with the decrease in city traffic density in Jakarta during the COVID-19 pandemic. Moreover, the air pollution index of PM10 and PM2.5 have been reduced by 15.74% and 9.48%, respectively (Table 1). It showed the major of primary aerosol was more PM10 and smaller content of PM2.5 (Seinfeld and Pandis, 2016). The percentage reductions of PM10 and NO_2 were observed more in urban areas.

Furthermore, PM2.5 and SO_2 indicated smaller decreases, while NO_2, CO, and PM10 showed much higher decreases. This occasion means that the traffic emission contributed to a higher decline than industrial sources such as oil refineries, power plants, petrochemical plants, and food processing facilities. In contrast, the simultaneous decline of NOx and PM2.5 is attributed to the rise of O_3 in Jakarta, with a higher rate by 4.06%. Li et al. (2019) explained the increase of O_3 could occur when the atmosphere has less NO to react with O_3 molecules.

Our results have compared atmospheric pollutants in other regions of the world during the lockdown period. For instance, Lia *et al.* (2020) found NO_2 has been reduced in Wuhan, China (53.3%), but O_3 was obtained increasing significantly (116.6%) during city lockdown. Another similar result was also reported by Menut *et al.* (2020), who found a decrease in NO_2 (30-50%) in all western European countries. Chen *et al.* (2020) found there were significant reductions for NO_2 (49%) and CO (37%) over the United States. In the South Asia region, a study by Singh *et al.* (2020) investigating 134 sites across India obtained a decrease in PM2.5 (40-60%), PM10 (30-70%), and NO_2 (20-40%) during the lockdown. The percentage reductions of PM2.5, PM10, and NO_2 were proportional to the population density. In addition, Abdullah *et al.* (2020a) revealed PM2.5 in Northern Malaysia showed the highest decrease during the Movement Control Order

(MCO), with 23.7%. If we compared it with our study, the percentage reduction was much higher than our study. However, the decline was related to the COVID-19 control measure, and it can be affected by environmental factors like geographical and meteorological conditions.

Table 1 The average air pollution index (API) of CO, NO_2, O_3, SO_2, PM10, and PM2.5 in Jakarta

Air Pollutant (API)	Before LSSR	During LSSR	Percentage Change (%)
CO	26.12	18.50	-29.17
NO_2	10.25	8.37	-18.34
O_3	58.25	60.62	+4.06
SO_2	25.87	24.25	-6.26
PM10	69.87	58.87	-15.74
PM2.5	91.0	82.37	-9.48

Spatial Variation of Tropospheric NO_2 Concentration in Jakarta

The concentration of tropospheric NO_2 was evaluated before and during the large-scale social restrictions (LSSR) period and 2019 year data (Fig. 2). The mean tropospheric NO_2 level before the LSSR period was 405×10^{13} molecule cm^{-2} and reduced by 36.8% during the LSSR period (Fig. 2b). The tropospheric NO_2 concentrations in 2020 were also compared with the 2019 year data. The mean tropospheric NO_2 during the LSSR was 256×10^{13} molecule cm^{-2} (Fig. 2c). There was a significant increase in tropospheric NO_2 in Jakarta that was 420×10^{13} molecule cm^{-2} in 2019 (Fig. 2a). The findings concluded that restrictions on anthropogenic activities such as industrial and transportation contributed to reducing NO_2 levels in the study area. Kanniah *et al.* (2020) noted in South East Asia, including Jakarta, there was also a marked decrease (27-30%) in tropospheric NO_2. They explained that anthropogenic activities like seasonal biomass burning had less impact on tropospheric NO_2 variation over this region during the lockdown phase. In Jakarta, the highest reduction of NO_2 concentrations was observed in industrial and urban areas across the city.

The Relationship between Air Pollutants and COVID-19 Cases

This study used Spearman correlation test to analyze the relationship between COVID-19 cases and air pollutants. The air pollutant data used in this analysis were taken from March to May 2020 during the COVID-19 pandemic. We revealed a significantly positive relationship of SO_2, CO, and PM2.5 with COVID-19 cases (Table 2). These outputs become evidence that air pollutants were a prominent factor in COVID-19 transmission. We compared our results with other studies to obtain a better understanding of the association between these variables. Yongjian *et al.* (2020) found a higher CO exposure in a short-term period could contribute to more COVID-19 cases. The study explained that 1 mg/m^3 rise in CO concentration could contribute to a 15.19% rise in COVID-19 cases. A literature review also discovered a positive relationship between SO_2 concentration and COVID-19 cases (Cole *et al.*, 2020). Chen *et al.* (2007) reported higher CO, SO_2, and NO_2 exposures were unsafe to human health and closely related to respiratory infection. Also, high air pollutants could intensify the risk of being infected by the COVID-19 virus (Rushayati *et al.*, 2020). Cole *et al.* (2020) reported an one-unit increase in PM2.5 concentrations was related to 9.4 more COVID-19 cases in the Netherlands. Similar results found by Zoran *et al.* (2020) and Fattorini and Regoli (2020) who obtained COVID-19 cases, were positively correlated with PM2.5 in Italy. The PM2.5 was also the environmental driver of the COVID-19 outbreak in China (Yao *et al.*, 2020). There was about a 2.24% increase in COVID-19 cases when PM2.5 concentrations increase by 10 $\mu g/m^3$ (Yongjian *et al.*, 2020). Overall, our results in the case of Jakarta were similar to the previous studies.

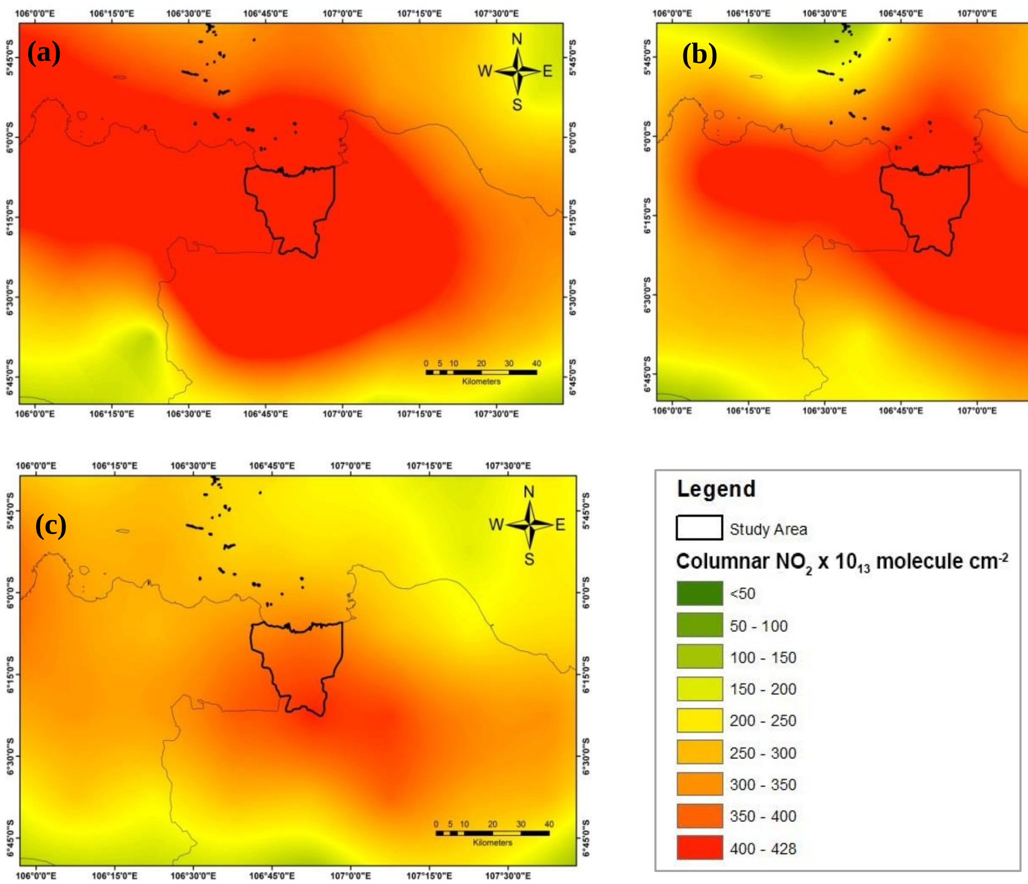

Figure 2 Spatial variation of tropospheric NO_2 concentration over Jakarta in the 2019 year data (a), before (b), and during the LSSR period (c)

Table 2 Spearman correlation between COVID-19 cases and air pollutants

	Pollutants	Total Cases	New Cases	Deaths
Spearman correlation coefficient	PM2.5	0.292*	0.086	-0.145
	CO	0.423**	-0.205	0.152
	SO_2	0.345**	0.306	0.167
	NO_2	0.051	0.143	0.080
	O_3	0.127	-0.084	-0.130
	PM10	0.369	0.277	0.062

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

To support our results, we have conducted a correlation test between air quality data and environmental factors. We found significant associations of SO_2 and CO with temperature in study area with r= -0.344; p<0.05 and r= -0.318; p<0.05, respectively (Table 3). Many studies have agreed temperature was closely linked to COVID-19 cases (Sahin, 2020). We could assume that the concentrations of SO_2 and CO in ambient air due to temperature influence also had the same impact on COVID-19 cases. The air quality index could affect the COVID-19 cases in the temperature range of 10-20°C and low relative humidity (Xu *et al.*, 2020). There was a significant association between weather, wind speed, and COVID-19 spread. Warmer weather would help depress the lifespan of the virus (Guo *et al.*, 2020; Rendana *et al.*, 2020). A high-temperature condition could contribute to an increased PM2.5 concentration (Abdullah *et al.*, 2020b). Yao *et al.* (2020) reported a higher PM2.5 concentration leads to more COVID-19 cases in China.

Furthermore, Huang *et al.* (2018) have explained if the annual temperature and gross domestic product of industry in China increase by 1%, the PM2.5 concentration would also increase by 35.7 and 29.1%, respectively. The fluctuation of PM2.5 concentration could be evaluated using the Deep Blue and the combined Dark Target and Deep Blue retrieval algorithm from MODIS data collection products. This technique had high accuracy and low root-mean-square error based on the study by Filonchyk and Hurynovich (2020) in China and Eastern Europe.

Table 3 The association between climate factors and air pollutants during COVID-19 pandemic

Parameter	PM2.5	SO_2	CO	NO_2	O_3	PM10	T	RH	P	W
PM2.5	1	-0.133	0.528**	0.571**	0.491**	0.174	0.313*	-0.233	-0.499**	-0.465**
SO_2	-0.125	1	0.226	-0.007	-0.029	0.168	-0.344*	0.221	0.353*	0.118
CO	0.528	0.226	1	0.564**	0.201	0.163	-0.318*	-0.170	-0.244	-0.433*
NO_2	0.571**	-0.007	0.564**	1	0.401*	0.038	0.178	-0.261	-0.094	-0.426*
O_3	0.491**	-0.029	0.201	0.401*	1	0.329	0.302	-0.236	-0.413*	-0.165
PM10	0.174	0.168	0.163	0.038	0.329	1	-0.266	0.248	0.357	-0.228

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)
T= Temperature, RH= Relative humidity, P= Precipitation, W= Wind speed

CONCLUSIONS

This study concluded PM2.5, SO_2, and CO were important factors in COVID-19 spread. These air pollutants were also closely associated with climate factors such as temperature, precipitation, and wind speed. The reduction of major air pollutants was observed during the LSSR period, but it might not solely depend on social control policy. Thus further studies need to examine other influencing factors that may relate to COVID-19 spread.

ACKNOWLEDGEMENTS

The author would like to thank the Jakarta Environmental Agency and Health Agency for providing air quality and COVID-19 cases data.

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