

## The Effects of Air Pollutants, Particulate Matter 10 (PM<sub>10</sub>), Sulphur Dioxide (SO<sub>2</sub>) and Nitrogen Dioxide (NO<sub>2</sub>), on Covid-19 Cases in Indonesia

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Received: 3 June 2022 Accepted: 27 June 2022 Published: 27 June 2022

### ABSTRACT

This study aims to analyse the effects of air pollutants on the number of COVID-19 cases in Indonesia. Three pollutants, i.e. Particulate matter 10 (PM<sub>10</sub>), Sulphur dioxide (SO<sub>2</sub>) and Nitrogen dioxide (NO<sub>2</sub>), were analysed. The study covers a period of 1 March 2020 to 31 December 2020 involving data from the cities of Jakarta, Bandung, Yogyakarta, Semarang and Surabaya in Indonesia.

This study used the Ordinary Least Square (OLS) method with the endurance test Robust Standard Errors. The regression results showed that PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> are statistically significant positive regressors of the number of COVID19 cases. Every 1 µg/m<sup>3</sup> increase in PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> concentrations is shown to cause an additional 2.65, 7.96 and 21.01 cases of COVID-19, respectively. The implementation of Large-Scale Social Restrictions (PSBB) has a statistically significant impact in curbing COVID-19 transmission; reducing 447.4 cases of COVID-19.

**Keywords:** COVID-19, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, regression

### INTRODUCTION

Coronavirus disease 2019 (COVID-19) or Several Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) first appeared in Wuhan City, China, in December 2019 (Jain *et al.*, 2000). COVID-19 spread swiftly around the world, including in Indonesia. Data from the Ministry of Health Indonesia showed that until 24 November 2021, the total number of COVID-19 cases worldwide reached 258,164,425 cases with 5,166,192 deaths. In Indonesia as of 24 November 2021, a total of 4,254,443 people were confirmed positive for COVID-19 with 143,766 deaths and a Case Fatality Rate (CFR) of 3.4%. As many as 4,102,700 people managed to recover from COVID-19.

The Indonesian government applied some measures to curb COVID-19 spread, one of them is the implementation of Large-Scale Social Restrictions, or *Pembatasan Sosial Berskala Besar* (PSBB) in Indonesian language. This research aims to identify the effects of air pollutants on the rise of COVID-19 cases in Indonesia during the implementation of PSBB. Studies analysing how air pollutants affect the number of COVID-19 cases and deaths, as well as that of other airborne diseases such as Sever Acute Respiratory Syndrome (SARS) are relatively voluminous. These studies used cities in China, Italy, the United States of America and Europe Union as the cases. See for example Contini and Costabile (2020), Cui *et al* (2003), Gautam (2020), Setti *et al* (2020), .. Such a study for Indonesian cities, however, is still relatively scarce, motivating the author to conduct such a study for five large Indonesian cities, i.e. Jakarta, Bandung, Yogyakarta, Semarang and Surabaya. The researcher hopes that results of this research will give some contributions to decision-makers in

designing regulations, especially the ones that are related to environmental factors that affect COVID-19 cases and death due to COVID-19.

On 2 January 2020, 41 people treated in hospitals by laboratories in Wuhan were confirmed positive for COVID-19. As many as 30 out of 41 people (73 per cent) were male, of which 13 people had congenital disease: 8 people had diabetes (20%), 6 people had hypertense (15%) and 6 people had cardiovascular (15%). The average age of the aforementioned people was 41 years old. Of that numbers, 13 of 41 people were treated in the ICU and 6 of them were deceased. Of the 13 people who had to be treated in the ICU had high plasma levels (Huang *et al.*, 2020).

The death rate due to COVID-19 increased. On January 24<sup>th</sup> 2020, laboratories in Wuhan stated that there were 835 patients infected by COVID-19 with 25 cases of them declared fatal. Clinical symptoms in those patients were similar to patients with SARS-CoV. The patients suffered from fever with cough, shortness of breath, fatigue, headache and diarrhoea. All mentioned patients also had pneumonia with abnormal chest CT including acute respiratory distress. From the tracing result, it was known that there was a family of the patients who consumed seafood from Huanan Seafood Market prior they were confirmed positive for COVID-19 (Huang *et al.*, 2020). Based on the progress of the tracing, 27 people were exposed to COVID-19 after they went to Huanan Seafood Market. Scientists then concluded that Huanan Seafood Market in Wuhan, China was the first place that COVID-19 appeared. Bat meat, one of the products sold in the Huanan market, is taken as the medium of COVID-19's transmission. The transmission from one person to others happened because of physical contact and droplets (Zhou *et al.*, 2021).

From Wuhan in China, COVID-19 spread swiftly around the globe. The World Health Organisation (WHO) declared the COVID-19 epidemic a Public Health Emergency of International Concern (PHEIC) on 31 January 2020 (Zhou *et al.*, 2021). On 11 March 2020, WHO declared the COVID-19 a pandemic due to its spreading to several countries, like Nepal, India and some countries in South Asia.

Indonesia was officially included as countries infected by COVID-19 on 2 March 2020. The first case was found in two people from Depok, West Java. From tracing results, it was suspected that they were infected by COVID-19 after getting physical contact with a Japanese citizen that visited Jakarta. The Japanese citizen was known to be infected by COVID-19 in Malaysia on his way home from Indonesia to Japan.

Some measures were taken by the Government of Indonesia to prevent the spread of COVID-19, including the PSBB and vaccination. Since August 2021, the trend of people infected by COVID-19 started to decrease. However, it does not mean that the spread has stopped. Countries worldwide, including Indonesia, still need to face Omicron, a new variant of SARS-CoV-2 or COVID-19.

The escalation of infection rate and death rate due to COVID-19 since the pandemic first appeared in Wuhan, China, in December 2019 and spread around the world has intrigued some researchers (Jain *et al.*, 2000). Researchers tried to analyse factors related to the spread of COVID-19. Some researchers found that COVID-19 transmits with direct physical contact and droplets from breathing. In some research, some researchers used air pollutants as the focus of their research. The consideration of using air pollutants is that the increase in air pollution is a threat to human health, especially related to respiratory disease (He Li *et al.*, 2020). Several previous research had proved

that there is a correlation between air pollution in the form of particulate matter in short-term exposure to ambient air towards the increased risk of respiratory disease. The increased risk happens because particulate matter in the air consists of toxic substances that could get in from the inhalation process and later will circulate in human's bloodstream and targeted organs, which will affect the exposed person (Firmansyah *et al.*, 2020).

Previous studies reported that pollutants like Nitrogen dioxide (NO<sub>2</sub>), Sulphur dioxide (SO<sub>2</sub>), Carbon monoxide (CO), Particulate matter 2.5 (PM<sub>2.5</sub>) and Particulate matter 10 (PM<sub>10</sub>) were the cause of cardiopulmonary disease. Nitrogen dioxide (NO<sub>2</sub>) leads to upper respiratory tract infections (URTI). Sulphur dioxide (SO<sub>2</sub>) and Carbon monoxide (CO) could lead to an increase in the risk of stroke, asthma and also lung cancer (Banerji, S. and Mitra, D., 2021).

Pollutants of Particulate matter 2.5 (PM<sub>2.5</sub>) and Particulate matter (PM<sub>10</sub>) with a diameter less than 0,5 mm can levitate in the air at a far distance. If the particles in the air are inhaled by humans, they can be distributed to the lungs and cause inflammation, oxidative stress and lung cancer (Valavanidis *et al.*, 2008; Anderson *et al.*, 2012; Kim *et al.*, 2015). Furthermore, several research also found that there is a correlation between air pollution and infectious disease transmission (He Li *et al.*, 2020), in example: worst air quality has been proven could increase the death due to SARS and increase the number of influenzas (Cui *et al.*, 2003; Landguth *et al.*, 2020).

The data showed that the air quality had significantly and positively affected the increase of daily cases of COVID-19 in Wuhan, China. Pollutants Particulate matter 2.5 (PM<sub>2.5</sub>) and Particulate matter 10 (PM<sub>10</sub>) became transmission media of SARS-CoV-2 and potentially increased the spread of COVID-19 (He Li *et al.*, 2020).

Particulate matter (PM) has a toxic effect that could enter human lungs and affect the physiological condition of human lungs also increase the risk of mortality and morbidity of COVID-19. Some researches found that there is a correlation between PM and COVID-19. PM<sub>2.5</sub>, which is smaller than PM<sub>10</sub>, has a higher ability to become a weighting factor in COVID-19 (Firmansyah *et al.*, 2020). There are two ways of COVID-19 transmission through PM. First, PM<sub>2.5</sub> blocks the human respiratory process and second, PM can form condensation nuclei for virus attachment (Lee *et al.*, 2014). PM<sub>2.5</sub> is relatively smaller in size so that it can penetrate alveoli and damage the respiratory tract. PM<sub>2.5</sub> became the most dominant factor that could transmit SARS-Cov-2 or COVID-19 (He Li *et al.*, 2020).

Research discussing the effects of pollutants on the increase of COVID-19 cases has been done in cities in several countries, like China, Italy and the USA. However, the aforementioned research has not been done in Indonesia. Through this research, it is hoped that the effect of pollutants on the increase in COVID-19 cases will be known, especially during the implementation of PSBB.

This research aimed to analyse the influence of air pollution on the increase of COVID-19 cases in Indonesia during the implementation of Large-Scale social restrictions (PSBB). The health of people that confirmed positive COVID-19 can get worse when exposed to air pollutants that to date always been known as one of the reasons for respiratory disease (Firmansyah *et al.*, 2020). However, currently, only a few people know about the influence of environmental factors on the increase of COVID-19 cases, even though there is some amount of evidence that the increase in air pollution rate in statistics could have increased the positive confirmed COVID-19 case and death due to COVID-19 (Persico *et al.*, 2021).

## METHODS

Data for this study were obtained from Kementerian Kesehatan (n.d.) for the period of 1 March 2020 to 31 December 2020 in five big cities in Indonesia, i.e. Jakarta, Bandung, Yogyakarta, Semarang and Surabaya. During this period, several phases of Large-Scale Social Restrictions (PSBB) was implemented. Variables used in this research are shown in Table 1.

Table 1. Research variables

No	Variables	Variable Codes
1	COVID-19 case	COVID19
2	Particulate Matter 10 (PM <sub>10</sub> ) concentration	PM10
3	Sulphur dioxide (SO <sub>2</sub> ) concentration	SO2
4	Nitrogen dioxide	NO2
5	Large-Scale Social Restrictions (PSBB)	DummyPSBB
6	Particulate Matter 10 concentration during PSBB	PM10XPSBB
7	Sulphur dioxide (SO <sub>2</sub> ) concentrate during PSBB	SO2XPSBB
8	Nitrogen dioxide (NO <sub>2</sub> ) concentrate during PSBB	NO2XPSBB
9	Observation city	idKota
10	Air humidity	Humidity
11	Daily average temperature	AVGTemp

Descriptive statistical variables in this research are shown in Table 2. The first panel shows COVID-19 as a dependent variable (Y) consisting of 1,408 cases with an average of 783.08 daily cases. Variable X in this research are pollutant Particulate matter 10 (PM<sub>10</sub>) with a total observation is 1,513 and average daily concentrate is 32.38 µg/m<sup>3</sup>, pollutant Sulphur dioxide (SO<sub>2</sub>) with a total observation is 1,452 and average daily concentrate is 24.23 µg/m<sup>3</sup>, and pollutant Nitrogen dioxide (NO<sub>2</sub>) with total observation is 1,149 and average of daily concentrate is 15.95 µg/m<sup>3</sup> as shown in table 2.

Table 2. Descriptive statistics

Variables	Observation	Mean	Standard Deviation	Min	Max
COVID19	1,408	783.076	105.7542	0	6,740
PM10	1,513	32.382	19.728	2.39	111
SO2	1,452	24.227	23.945	1	159
NO2	1,149	15.950	18.966	1	148
DummyPSBB	1,530	0.831	0.375	0	1
idKota	1,530	3	1.415	1	5
Kota1	1,530	3	1.415	1	5
PM <sub>10</sub> PSBB	1,513	26.653	22.132	0	111
SO <sub>2</sub> PSBB	1,452	22.141	25.286	0	159
NO <sub>2</sub> PSBB	1,149	13.939	13.939	0	148

The objective of this research is to test the influence of air pollutants: Particulate matter 10 (PM<sub>10</sub>), Nitrogen dioxide (NO<sub>2</sub>) and Sulphur dioxide (SO<sub>2</sub>) on the increase of COVID-19 cases in Indonesia using the Ordinary Least Square (OLS) method. The analysis was started by composing a

descriptive statistic from the data that will be used in the double linear regression model. The goal of this descriptive statistic is to decide the base feature from datasets of the observed data. There are three methods to estimate the panel data (Baltagi, 2005; Wooldridge, 2016). The three methods are Common Effect (CE), Fixed Effect (FE) and Random Effect (RE). Of the three models, the researcher picked one that can be used as the model for estimating panel data parameters.

Later on, the author did three tests to choose whether to use Common Effect, Fixed Effect or Random Effect. The tests are F Statistic Test (Chow Test) to choose between the Common Effect or Fixed Effect method. Hausman Test to choose between Fixed Effect or Random Effect and Lagrange Multiplier (LM) Test to choose between Common Effect or Random Effect.

The regression model used in this research has autocorrelation, heteroscedasticity and normality. In econometrics, this terminology is known as Heteroscedasticity Autocorrelation Spatial Correlation (HACSC) (Vogelsang, 2012). There are several methods to solve this problem, Beck & Katz (1995) suggested using panel-corrected standard errors (PCSE) (Hoechle, 2007). Monte Carlo analysis mentioned that panel-corrected standard errors is suitable for the regression model.

Robust Standard Errors can also be used in a regression model. Robust regression is essential to solve the problem in Ordinary Least Squares (OLS), like autocorrelation, heteroscedasticity and normality (Alma, 2011). Robust Standard Errors is usually applied in cross-section regression, especially in larger data. Even nowadays, it is not rare that researchers implement Robust Standard Errors so it will be easier to get a result that is more resistant to the problems occurring in OLS regression. In this research, the researcher used Robust Standard Errors to overcome the autocorrelation, heteroskedasticity and normality problems.

Based on the data that the researcher received and the objective of this research, that is to analyse the influence of air pollutants on the increase of COVID-19 cases, then the double econometric linear regression model that the researcher used was:

$$Y_{it} = \alpha + \beta_1 PM_{10it} + \beta_2 SO_{2it} + \beta_3 NO_{2it} + DummyPSBB_{it} + humidity_{it} + \epsilon_{it} \quad (1)$$

Y is confirmed positive COVID-19 cases,  $\alpha$  is constant,  $\beta$  is coefficient,  $\epsilon$  is an error term,  $i$  is the observed city and  $t$  is the period of observation.  $PM_{10}$ ,  $SO_2$  and  $NO_2$  are the pollutants in  $\mu g/m^3$  which become independent variables or X, PSBB is Large-Scale Social Restriction during COVID-19 pandemic.

## RESULTS AND DISCUSSION

This research's objective is to know the effects of air pollutants, which are Pollutant Matter 10 ( $PM_{10}$ ), Sulphur dioxide ( $SO_2$ ) and Nitrogen dioxide ( $NO_2$ ), on the number of COVID-19 cases in Jakarta, Bandung, Yogyakarta, Semarang and Surabaya. Data were obtained from Ministry of Health's official records, covering the period of 1 March 2020 to 31 December 2020 (Kemenkes, n.d.). The regression result from Ordinary Least Squares (OLS) is shown in Table 3.

Table 3. The effects of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> on COVID-19 cases

	<b>COVID19</b>
PM <sub>10</sub>	2.650** (1.291)
SO <sub>2</sub>	7.955*** (1.571)
NO <sub>2</sub>	21.01*** (1.955)
DummyPSBB (1 = PSBB 0 = no PSBB)	-447.4** (151.2)
Humidity	-16.67*** (3.581)
_Cons	366.2*** (4.96)
N	971
r <sup>2</sup>	0.49
r <sup>2</sup> <sub>a</sub>	0.48

Notes: \*\* = statistically significance at  $\alpha = 5\%$

\*\*\* = statistically significance at  $\alpha = 2.5\%$

As shown in Table 3, PM<sub>10</sub> air-concentration is a statistically significant positive regressor for the number of COVID-19 cases; every 1  $\mu\text{g}/\text{m}^3$  increase in PM<sub>10</sub> concentration could lead to 2.65 additional COVID-19 cases. SO<sub>2</sub> is also shown to be a statistically significant positive regressor for the number of COVID-19 cases; every 1  $\mu\text{g}/\text{m}^3$  increase of SO<sub>2</sub> concentration add another 7.96 COVID-19 cases. So is NO<sub>2</sub>, where an increase of NO<sub>2</sub> concentration by 1  $\mu\text{g}/\text{m}^3$  increases the number of COVID-19 cases by 21.01.

On the contrary, PSBB is shown to be statistically significant negative regressor of the number of COVID-19 cases, in which the implementation of PSBB decreases the number of cases by 447.4.

### Robustness Check

The next step was a robustness check or endurance test. In this step, the data was analysed with a similar model as pollutant datasets, which are PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub>. The researcher conducted this test to see how far the consistency of the influence of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> is towards the increase of COVID-19 cases from the first day until the seventh day after the observation. The result of the robustness check is shown in Table 4.

The results showed that there is a statistical consistency in the influence of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> on the number of COVID-19 cases. There is also a variation of significant rate between the three pollutants. The effects of PM<sub>10</sub> on the first day is shown to be statistically significant, with the statistical significance becoming stronger on the second to the seventh day. Pollutants SO<sub>2</sub> and NO<sub>2</sub> are shown to be significant regressors of the number of COVID-19 cases at  $\alpha = 2.5\%$ . The PSBB is statistically significant in decreasing COVID-19 cases to 479.7 cases in the first day.

Table 4. Robustness check

Variables	t_1	t_2	t_3	t_4	t_5	t_6	t_7
	COVID19	COVID19	COVID19	COVID19	COVID19	COVID19	COVID19
				9	9	9	9
PM <sub>10</sub>	3.311** (1.324)	3.929*** (1.336)	4.430*** (1.270)	5.423*** (0.853)	5.426*** (1.280)	6.367*** (1.280)	6.290*** (1.275)
SO <sub>2</sub>	10.35*** (2.436)	10.24*** (2.294)	10.63*** (2.222)	11.63*** (2.214)	11.27*** (2.223)	12.51*** (2.492)	11.26*** (2.383)
NO <sub>2</sub>	17.10*** (3.520)	17.28*** (3.198)	16.68*** (2.984)	14.67*** (2.938)	15.26*** (3.103)	14.31*** (3.135)	16.49*** (3.069)
DummyPSB B	-479.7*** (92.51)	-423.7*** (81.91)	-425.5*** (93.58)	- 410.0*** (82.90)	- 433.1*** (96.60)	- 351.7*** (90.52)	- 380.6*** (104.0)
Humidity	-15.52*** (4.045)	-14.50*** (4.084)	-13.82*** (4.112)	- 12.04*** (4.169)	- 12.10*** (4.154)	- 11.12*** (4.015)	- 10.94*** (3.865)
PM <sub>10</sub> PSBB	4.524 (3.282)	2.824 (3.207)	2.145 (3.355)	1.078 (2.849)	1.561 (3.346)	0.225 (3.167)	2.693 (3.646)
SO <sub>2</sub> PSBB	18.36*** (5.236)	20.72** (8.147)	22.21*** (6.833)	20.32*** (5.894)	22.91*** (5.944)	18.76*** (6.190)	15.48** (7.816)
NO <sub>2</sub> PSBB	-17.44*** (5.236)	-19.37*** (5.295)	-19.72*** (5.014)	- 15.91*** (4.839)	- 19.19*** (4.705)	- 16.34*** (4.957)	- 17.39*** (6.392)
Constant	325.2** (130.6)	279.9** (132.2)	249.7* (130.0)	185.3 (129)	189.4 (129.8)	126.2 (129.8)	125.1 (120.)
Observations	968	964	960	957	956	956	952
R-squared	0.471	0.470	0.474	0.463	0.465	0.482	0.484

Notes: \*\* = statistically significance at  $\alpha=5\%$ \*\*\* = statistically significance at  $\alpha=2.5\%$ 

## CONCLUSIONS

The objective of this research is to analyse the effects of Particulate matter 10 (PM<sub>10</sub>), Sulphur dioxide (SO<sub>2</sub>) and Nitrogen dioxide (NO<sub>2</sub>) on the number of COVID-19 cases. The results showed that PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> had a statistically significant effects on the number of COVID-19 cases. These results are consistent with those of Bashir *et al.*, 2020 who found a strong correlation between air pollutants, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and CO and the COVID-19 pandemic in California, USA.

This study's finding that NO<sub>2</sub> statistically significantly affect the number of COVID-19 cases offers an additional support to Ogen (2020)'s finding that 3,487 (78%) out of 4,443 COVID-19 deaths

in Italy, Spain, France and Germany occurred in areas with a high rate of NO<sub>2</sub> concentration, such as in Northern Italy and Spain's city centres.

This study, however, does not use pollutant sources, e.g. household and industrial energy consumption and motor vehicle emission, as explanatory variables. A future analysis of how pollutant sources affect the transmission of airborne diseases would be very useful for both academic and policy-making purposes.

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