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Article

Identification of Dominant Factor for Air Pollution Fluctuations at the Beginning of Covid-19 Large-Scale Social Restrictions (PSBB) in Jakarta

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Abstract

A Coronavirus Diseases 2019 (COVID-19) stroke many countries at the beginning of 2020. It had an impact not only in the health field but also on the environment. Some countries enforced to lockdown policy. This condition impacted to increase the air quality in big cities in the world. However, the Indonesian government ruled large scale social restriction (PSBB) since April 2020. PSBB is not as strict as lockdown in other countries because society could go out for some crucial reason such as working, and getting food. Many researchers reported that the lockdown policy decreased air pollution in some big cities such as Beijing, Italy, etc. Therefore, this study aimed to identify the dominant factor of air pollution fluctuation 1-month before PSBB, during PSBB and 1-month after PSBB. Is only PSBB reducing social mobility caused changes of air pollutions such as CO, SO2, NO2, PM, and O3 or did meteorological factors such as relative humidity and wind speed also impact air pollutions concentration? To calculate the dominant factor by highest contribution value, this study used multiplication between the slope of pollutant to relative humidity or wind speed or social mobility and the slope of relative humidity or wind speed or social mobility to the time. The result showed that the social mobility at 1-month before PSBB, during PSBB and 1-month after PSBB was the dominant factor of CO decreasing at the rate of -0.44, -0.01, and -0.11 ppm. However, the contribution of relative humidity, wind speed and social mobility to other air pollutions did not always same as the trend of air pollutions.
Keywords: *air quality, dominant factor, slope, and trend*

1. Introduction

In late December 2019, the first new variant virus was reported in Wuhan, China. It has characteristics of a high infection and fast transmission from human to human[(1)]. Some countries informed that some patients were infected by the same virus in Wuhan in January 2020. Last January 2020, The Director-General of WHO issued the novel coronavirus outbreak public health emergency of international concern (PHEIC). Subsequently, that virus was named Coronavirus Diseases 2019 (Covid-19) by World Health Organization (WHO) on 11 February

2020[2]. Some countries decided to lockdown their regions for limiting people movement, therefore it could prohibit the Covid-19 infections such as China, New Zealand, Vietnam, Australia, Malaysia, etc. The national lockdown or local lockdown reduced industrial activities and transportation. Therefore, it decreased fossil-fuel consumption in the world.

Covid-19 struck Indonesia which has a population of about 270 million. The first case of Covid-19 was reported on 02 March 2020 in Jakarta [3]. The increasing case of Covid-19 happen in late March causing Joko Widodo as President of Republic Indonesia announced to apply Large-Scale Social Restrictions (PSBB). Different from lockdown, PSBB still has allowed people to do some activities in a public area. Society still has gone out from their home, but for some reasons such as working and eating. However, people must follow the health protocol when they went out of their homes. PSBB has allowed people worked from home so that people in the office would be fewer. The number of people working in the office decreased at the time of the PSBB, this indicates that the use of transportation has also decreased.

Jakarta as the capital city of Indonesia has an area of about 662,33 km^2 with a population 10,57 million in 2020 so that the city density of Jakarta is about 16 people per km^2. This situation could triggered high air pollution levels in Jakarta caused by anthropogenic activities. Jakarta placed the most polluted city in 2019 based on airvisual.com data [4]. The main source of pollutions in all big cities in Indonesia is fossil fuel vehicle emissions. There are about 70 % pollutions in big cities from transportation activities[5]. The distribution of pollutions in Jakarta is centred in North Jakarta and the Central Jakarta region at night and in South Jakarta in the afternoon[6]. The distribution of pollutions is influenced by meteorological factors such as wind, relative humidity, rain.

Air pollution is the number of substance gasses in the air interfering with human health or environments such as ground-level ozone, particulate matter, Carbon Monoxide, Sulfur Dioxide, and Nitrogen Dioxide. Pollutions are separated into primary pollutions extracted directly into atmospheres such as Carbon Dioxide, Carbon Monoxide, Nitrogen Monoxide, Sulfur Dioxide, and particulate matter and secondary pollutions extracted not directly into the atmosphere such as Nitrogen Dioxide, Ozone, and Sulfuric acid droplets[7]. Air Quality Index (AQI) is the index used to measure contamination levels in the atmosphere.

Many studies researched air pollution quality during the lockdown. They reported that there were decreasing in air pollutions level until 40 % in some cities during the lockdown period[8,9]. Among pollution gasses, Nitro Oxide (NO_2) was the most gas reduced and Ozone

(O_3) was the most increased during the lockdown in New Delhi and Wuhan[10]. Differ from most countries in the world applying lockdown, Indonesia has applied PSBB to prohibit the spreading of Covid-19. PSBB has not totally restricted human mobility, therefore there is still human mobility.

Therefore, this research studied air quality conditions before, during and after the first PSBB period. We examined the concentration of 5 pollutions (Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitro Dioxide (NO_2), Particulate Matter (PM), and ozone (O_3)), and dominant factor impact to air pollution fluctuations in Jakarta 1-month before PSBB, during PSBB and 1-month after PSBB period in Jakarta.

2. Materials and Methods

The air pollutions data used in this study was the daily monitoring concentration data (CO, SO_2, NO_2, PM, and O_3) from air quality observation stations from February 2020 to May 2020 and the daily average monitoring concentration data (CO, SO_2, NO_2, PM, and O_3) from air quality observation stations from 09 March 2020 to 09 April 2020 (1-month before PSBB), from 10 April to 23 April 2020 (during PSBB), and from 24 April to 24 May 2020 (1-month after PSBB). This study used five air quality stations, then calculated their average data to represent CO, SO_2, NO_2, PM, and O_3 in Jakarta.

Table 1. The station of air quality in Jakarta

No	Name of Station	Latitude	Longitude
1	SPKU Bundaran HI (DKI 1)	-6,22	106,83
2	SPKU Kelapa Gading (DKI 2)	-6,15	106,90
3	SPKU Jagakarsa (DKI 3)	-6,33	106,82
4	SPKU Lubang Buaya (DKI 4)	-6,30	106,90
5	SPKU Kebon Jeruk (DKI 5)	-6,19	106,77

The number of mobility in Jakarta will influence the concentration of pollutions. Those data gained from https://www.google.com/covid19/mobility/ . The used parameter was retail and recreation mobility. The mobility of people in retail dan recreation was only in Jakarta region and it was not separated to West Jakarta, East Jakarta, North Jakarta, and South Jakarta. Therefore, the data mobility in Jakarta was used to represent mobility data in those regions.

Wind speed and relative humidity data from Tanjung Priok Maritim Station (BMKG) and Kemayoran Meteorological Station (BMKG). This study averages relative humidity and wind speed data in Tanjung Priok and Kemayoran to represent Jakarta condition.

Dominant factor impacted to air pollutions fluctuations during PSBB was calculated by trend analysis. This study used linear regression (x = a + bt) to calculate the slope of the trendline by equation 1.1:

$$b = [n \sum_{i=n}^{n} x_i t_i - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} t_i)] / [n \sum_{i=n}^{n} t_i^2 - (\sum_{i=1}^{n} t_i)^2] \quad (1.1)$$

In the function, $y = f(x_1, x_2, x_3)$, the fluctuation of variable y can be described by equation 1.2 :

$$dy = \sum \frac{\partial f}{\partial x_i} dx_i \quad (1.2)$$

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In addition, if y as time-series data, we can assume [18] :

$$\frac{dy}{dt} = \sum \frac{\partial f}{\partial x_i} \frac{dx_i}{dt} \quad (1.3)$$

$$\frac{dy}{dt} = \frac{\partial y}{\partial x_1}\frac{dx_1}{dt} + \frac{\partial y}{\partial x_2}\frac{dx_2}{dt} + \frac{\partial y}{\partial x_3}\frac{dx_3}{dt} + \varepsilon \quad (1.4)$$

This study assumes that air pollutions (y) can be influenced by wind speed data (x_1), relative humidity (x_2), and social mobility (x_3). Moreover, the contribution of wind speed, relative humidity, and social mobility to air pollutions can be represented by partial derivative and long-term trend in x_i. Then, the proportion of contribution was calculated by:

$$C = Cx_1 + Cx_2 + Cx_3 + \cdots + c \quad (1.5)$$

where C = the contribution of the some factors, Cx_i is the contribution of single parameter (wind speed / relative humidity / social mobility), $Cx_1 + Cx_2 + Cx_3$ is the sum of all parameter contribution to air pollution trend line and ε is error.

3. Results and Discussion

3.1. Air Pollution Changes Before, During And After PSBB

The average concentrations of pollutions in Jakarta are illustrated in Figure 1, with trendline on the long period (01 January to 31 May 2020), 1-month before Large-Scale Social Restrictions (09 March to 09 April 2020), The first Large-Scale Social Restrictions period (10 April to 23 April 2020), 1-month after Large-Scale Social Restrictions (24 April to 23 May 2020). Generally, there are different trends among pollutions (PM_{10}, SO_2, CO, O_3, NO_2). Sulphur Dioxide (SO_2), Carbon Monoxide(CO), and Nitrogen Dioxide (NO_2) decreased between 01 January and 31 May 2020, on the other hand, Particulate Matter 10 (PM_{10}) and Ozone (O_3) increased in that period.

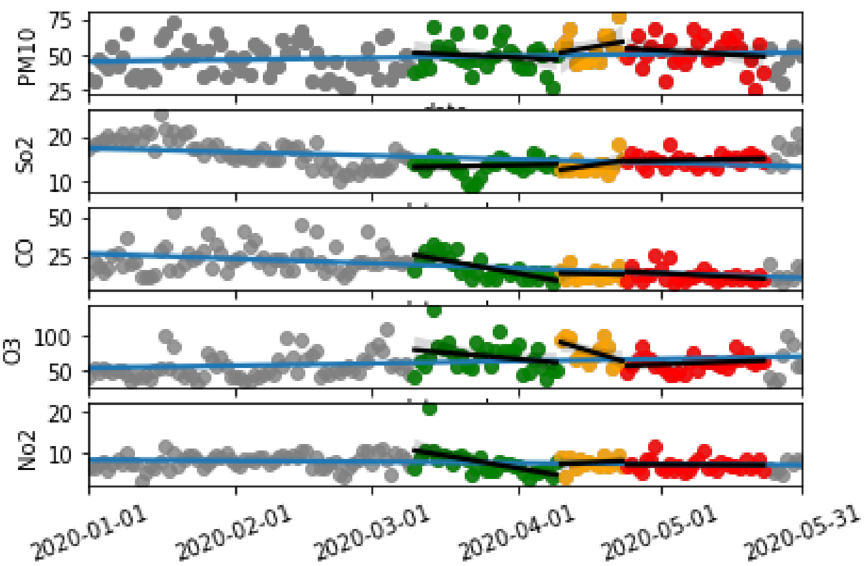

Figure 1. Pollutions trendline chart. All period from 01 January 2020 to 31 May 2020 (grey circles), 1-month before PSBB (green circles), PSBB Period (Yellow circles), 1-month after PSBB (red circles)

The slopes of pollutions trendline in the long period are 0.04 (PM_{10}), -0.03 (SO_2), -0.1 (CO), 0.1 (O_3), and -0.01 (NO_2), respectively. This situation has not analyzed whether this decrease or increase is due to weather factors or social mobility. The fluctuation of pollutions is also influenced by meteorological factors such as wind, air temperature, humidity, and precipitation(11). Therefore, the trendline in long period can be influenced by meteorological factors because starting period trendline is in January when the peak of the rainy season in the Jakarta region, whereas January could be the lowest point of air pollutions. NO_2 and PM_{10} would be reduced during when rainy season because rain washes out air [(12)].

Table 2. The slope of air pollutions

Period	Slope				
	PM10	SO_2	CO	O_3	NO_2
Before 1-month	-0,1	0,01	-0,5	-0,4	-0,18
PSBB	0,58	0,15	-0,05	-2,08	0,05
After 1-month	-0,16	0,01	-0,09	0,12	-0,01

A shorter time analysis is needed to study the impact of PSBB on air quality in Jakarta. Before announcing PSBB, the government applied for a work from home (WFH) policy on 15 March 2020. WFH reduced social mobility. Therefore, all pollutions showed a decline from 09 March to 09 April 2020, except Sulfur Dioxide (SO_2). The slope decreasing of Carbon Monoxide(CO), and Nitrogen Dioxide (NO_2), Particulate Matter 10 (PM_{10}) and Ozone (O_3) were -0.5, -0.18, -0.1, and -0.4 respectively. Carbon Monoxide and Ozone were a higher slope decreasing than others.

In the PSBB period, there is an increase of pollutions, except Ozone and Carbon Monoxide. The slope of decreasing trendline ozone is higher than other pollutions, about -2. Carbon monoxide has a slope of trendline about -0.05. PM_{10}, SO_2, and NO_2 have an in the slope of trendline about 0.58, 0.15, 0.05 respectively.

In the 1-month after the first PSBB period, there is an increase of SO_2 and Ozone. The slope of trendline SO_2 and Ozone are 0.01 and 0.12. Other pollutions (PM_{10}, CO, and NO_2) decreased steadily. PM_{10}, CO, and NO_2 have trendline slopes about -0.16, -0.09, -0.01, respectively. This period is called the transition PSBB period when there are some relaxation policies such as retail mall reopening, work from office increasing and flight and train transportation reopening. That condition was captured by google mobility (figure 2). There was increasing mobility since 25 April 2021, so greenhouse gasses intensity would go up.

3.2. Social Mobility Before, During And After PSBB

Figure 2 shows that there was a drop in mobility index since 15 March 2021 because of Indonesia government policy to reduce the rate of human movement in a public area by Work From Home system, retail mall closing and flight and train transportation closing. The decreasing mobility occurred until the mid of April 2021. This condition approved that the social mobilities can influence the distribution of air pollutions [13].

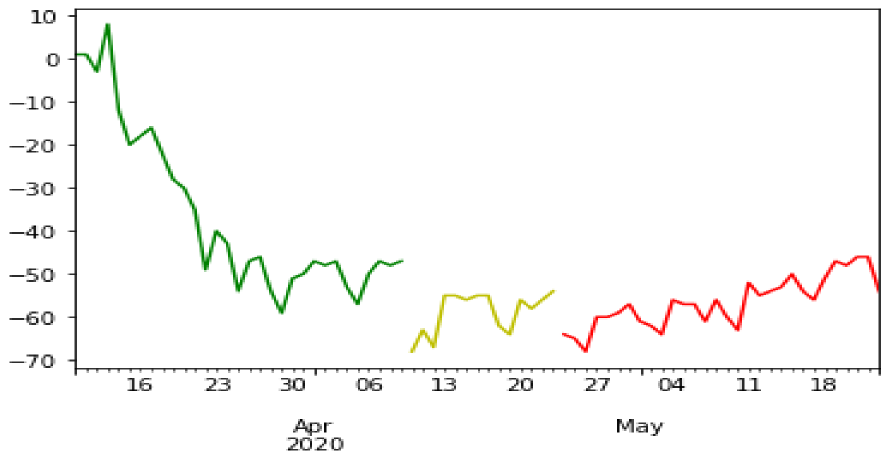

Figure 2. Social mobility index 1-month before (green) , during PSBB (yellow), 1-month after PSBB (red)

The table 3 shows that the lowest decrease of social mobility in 1-month before PSBB period indicated by -1.89. Then, the slope of social mobility increased during PSBB and after 1-month period because the economic needs push the society to go out from their homes. During PSBB, the worker was called by employer to go work from office. Therefore, the social mobility increased in during PSBB because the government issued the policy to work from office again. The mobility slope during PSBB and 1-month after PSBB were 0.59 and 0.45.

Table 3. The slope of Social Mobility

Period	Mobility slope
Before 1-month	-1,89
PSBB	0,59
After 1-month	0,45

3.3. Meteorological Data Before, During and After PSBB

One of the factors that influences air pollutions is wind. The wind has a role not only in pollutions distribution but also in correlations between pollutions (13). Wind can flow pollutions from the industrial areas, traffic areas and fossil fuel power plants to other areas. The wind speed of more than 2 m/s can reduce pollutions (14,15,16). Table 4 shows that the slope of wind speed decreased by -0.02 in 1-month before PSBB, then it increased in during PSBB and 1-month after PSBB by 0.06 and 0.01.

Table 4. The slope of Wind speed (WS), and Relative Humidity (RH)

Period	**Slope**	
	WS	RH
Before 1-month	-0,02	0,03
PSBB	0,06	-0,77
After 1-month	0,01	-0,16

Another meteorological factor impacting the dispersion of pollutions is relative humidity. The relative humidity has impact to some air pollutants such as PM 10 (17). In 1-month before PSBB period, the slope of RH was 0.03. Then, it decreased in PSBB period and 1-month period because Jakarta enters dry season. Table 5 shows the contributions of relative humidity, wind speed and social mobility to the trend of some air pollutants (PM10, SO_2, CO, O_3 and NO_2) in 1-month before, during and 1-month after PSBB period. Social mobility is the dominant factor causing air pollutions fluctuation in Carbon in almost all period in Jakarta. Furthermore, the second dominant factor of air pollution fluctuation is relative humidity.

3.4. The Contribution To Air Pollutions Before, During And After PSBB

Table 5. The contribution to air pollutions before, during and after PSBB

Period	Contribution to PM10				PM10 trend	error
	C_{X1}	C_{X2}	C_{X3}	C		
Before 1-month	0,02	0,03	0,09*	0,14	-0,10	-0,25
PSBB	1,13*	0,04	-0,45	0,72	0,58	-0,14
After 1-month	0,13	0,02	-0,23*	-0,08	-0,16	-0,08

Period	Contribution to SO_2				SO_2 trend	error
	C_{X1}	C_{X2}	C_{X3}	C		
Before 1-month	-0,004	-0,004	-0,013*	-0,022	0,01	0,03
PSBB	0,111*	-0,014	0,044	0,140	0,15	0,01
After 1-month	0,014	-0,002	0,015*	0,027	0,01	-0,02

Period	Contribution to CO				CO trend	error
	C_{X1}	C_{X2}	C_{X3}	C		
Before 1-month	0,01	-0,01	-0,43*	-0,44	-0,50	-0,06
PSBB	0,18	-0,01	-0,17*	-0,01	-0,05	-0,04
After 1-month	0,03	-0,01	-0,13*	-0,11	-0,09	0,02

Period	Contribution to O_3				O_3 trend	error
	C_{X1}	C_{X2}	C_{X3}	C		
Before 1-month	0,05*	0,04	0,03	0,11	-0,40	-0,52
PSBB	-0,27	-0,12	-1,59*	-1,99	-2,08	-0,09
After 1-month	-0,07	-0,08	0,53*	0,37	0,12	-0,25

Period	Contribution to NO_2				NO_2 trend	error
	C_{X1}	C_{X2}	C_{X3}	C		
Before 1-month	0,003	0,003	-0,18*	-0,17	-0,18	0,00
PSBB	0,03	-0,02	-0,03*	-0,02	0,05	0,07
After 1-month	-0,01*	-0,002	0,004	-0,004	-0,01	-0,01

* means the highest contribution trend

In Particulate Matter (PM 10), relative humidity has highest contribution estimation than other factors in 1-month before PSBB, but it has increasing impact to air pollutions. The change in relative humidity, wind speed and social mobility led to an increase at 0.02, 0.03 and 0.09 ppm. However, the PM 10 contribution estimations before PSBB has high error. It indicated that there were other factors influencing PM10 concentration such as industry activities, power plants, and air temperature [(19)]. During PSBB, relative humidity, wind speed and social mobility have contributions 1.13, 0.04, -0.45 ppm to an increase of PM10 concentration. Furthermore, the contributions of relative humidity, wind speed and social mobility were 0,13, 0.02 and -0.23 ppm in 1-month after PSBB. It is clear that social mobility has highest contribution to PM10 concentration almost in all period.

The contribution of relative humidity, wind speed and social mobility to SO_2 were -0.004, -0.004 and -0.013 ppm in 1-month before PSBB. During PSBB, relative humidity and social mobility have led to an increase of SO_2 at rate of 0.111 and 0.044 ppm, but wind speed has led to a decrease of SO_2 at rate -0.014 ppm. The contribution to SO_2 from relative humidity, wind speed and social mobility have led to an increase of SO_2 at rate of 0.014 and 0.015 ppm. In contrast, SO_2 was decreased by wind speed in that period.

The estimation of sum contribution from all factors (relative humidity, wind speed and social mobility) to CO (C) have led to a decrease of CO in all period at -0,44, -0,01, and -0,11 ppm. Relative humidity shows increasing effect in all period at 0.01, 0.18, and 0.03 ppm. In contrast, wind speed and social mobility have led to a decrease of CO in all period. Social mobility has highest contribution to CO fluctuation in all period at rate of -0,43, -0,17,-0,13 ppm.

The contribution of all factors (relative humidity, wind speed and social mobility) has led to Ozone (O_3) decreasing at rate of -0.27, -0.12, -1.59 ppm during PSBB period. It means that social mobility was highest factor dominant to decrease ozone concentration during PSBB period. However, the contribution of all factors (relative humidity, wind speed and social mobility) at rate of 0.05, 0.04, 0.03 ppm to O_3 trendline in 1-month before PSBB. A decrease contribution rate of relative humidity and wind speed to ozone at -0.07 and -0.08 ppm in 1-month after PSBB.

Nitro Oxide (NO_2) trend line was contributed by relative humidity, wind speed and social mobility at rate of 0.03, 0.03 and -0.018 in 1-month before PSBB period. During PSBB, the contribution of relative humidity, wind speed and social mobility was at rate of 0.03, -0.02, -

0.03 ppm. Then, the relative humidity, wind speed and social mobility contribution to NO_2 were at rate -0.01, -0.0002, and 0.004 ppm.his section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

5. Conclusions

This study conducted to know the dominant factor of air pollutions in 1-month before PSBB, during PSBB and 1-month after PSBB. Each air pollutions in that period has different trend. Not all air pollutants did not decrease in PSBB period. Carbon Monoxide was only pollution gas which has decreased trend line in all period. Then, the social mobility has highest contribution to some air pollutants in almost all period. It was clearly seen in the contribution of social mobility to Carbon Monoxide (CO) in all period. However, social mobility or meteorological factors (relative humidity and wind speed) was not clearly seen in the contribution to other pollutants (PM10,SO_2,O_3,NO_2), because the contribution of those factors to them has different effect to other pollutants trend line sign.

References

1. Ciotti, M., Angeletti, S., Minieri, M., Giovannetti, M., Benvenuto, D., Pascarella, S., ... & Ciccozzi, M. COVID-19 outbreak: an overview. *Chemotherapy* 2019, 64(5-6), 215-223.
2. Qin, C., Zhou, L., Hu, Z., Yang, S., Zhang, S., Chen, M., ... & Wang, W. Clinical characteristics and outcomes of COVID-19 patients with a history of stroke in Wuhan, China. *Stroke* 2020, 51(7), 2219-2223.
3. Djalante, R., Lassa, J., Setiamarga, D., Sudjatma, A., Indrawan, M., Haryanto, B., ... & Warsilah, H. Review and analysis of current responses to COVID-19 in Indonesia: Period of January to March 2020. *Progress in Disaster Science* 2020, 6, 100091.
4. Barus, L. S., & Rachman, H. O. Impact of Car-Free Day on air pollution and its multifarious advantages in Sudirman-Thamrin Street, Jakarta. *GEOMATE Journal* 2019, 17(62), 167-172.
5. Kusminingrum, N., & Gunawan, G. Polusi udara akibat aktivitas kendaraan bermotor di jalan perkotaan Pulau Jawa dan Bali. Jurnal, Jakarta, Puslitbang Jalan dan Jembatan.
6. Turyanti, A., June, T., Aldrian, E., & Noor, E. Analisis Pola Dispersi Partikulat Dan Sulfurdioksida Menggunakan Model Wrfchem Di Sekitar Wilayah Industri Tangerang

Dan Jakarta (Analysis of Particulate and Sulfurdioxide Pattern Dispersion Using Wrfchem Model Over Industrial Area in Tangerang). *Jurnal Manusia dan Lingkungan* 2008, 23(2), 169-178.

7. Rodríguez-Urrego, D., & Rodríguez-Urrego, L. Air quality during the COVID-19: PM2. 5 analysis in the 50 most polluted capital cities in the world. *Environmental Pollution* .2020, 115042.
8. Kumari, P., & Toshniwal, D. Impact of lockdown on air quality over major cities across the globe during COVID-19 pandemic. *Urban Climate* 2020, 34, 100719.
9. Lian, X., Huang, J., Huang, R., Liu, C., Wang, L., & Zhang, T. Impact of city lockdown on the air quality of COVID-19-hit of Wuhan city. *Science of the Total Environment* 2020, 742, 140556.
10. Mahato, S., Pal, S., & Ghosh, K. G. Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. *Science of the total environment* 2020, 730, 139086.
11. Fan, C., Li, Z., Li, Y., Dong, J., van der A, R., & de Leeuw, G. Does reduction of emissions imply improved air quality?. *Atmospheric Chemistry and Physics Discussions* 2020, 1-34.
12. Kim, S., Hong, K. H., Jun, H., Park, Y. J., Park, M., & Sunwoo, Y. Effect of precipitation on air pollution concentration in Seoul, Korea. *Asian Journal of Atmospheric Environment* 2014, 8(4), 202-211.
13. Elminir, H. K. Dependence of urban air pollutions on meteorology. *Science of the Total Environment* 2005, 350(1-3), 225-237.
14. Liu, Z., Shen, L., Yan, C., Du, J., Li, Y., & Zhao, H. Analysis of the Influence of Precipitation and Wind on PM2. 5 and PM10 in the Atmosphere. *Advances in Meteorology* 2020, 2020.
15. Guo, R., & Jiang, Y. Effects of Precipitation on Air Pollution in Spring and Summer in Lanzhou. *In E3S Web of Conferences* 2020, Vol. 194, p. 04007.
16. Zhao, X., Sun, Y., Zhao, C., & Jiang, H. Impact of precipitation with different intensity on PM2. 5 over typical regions of China. *Atmosphere* 2020, 11(9), 906.
17. Sharma, R. C. Investigation of Variability of Some Gaseous and Particulate Pollutants over Delhi, Northern India (28° 40′ N, 76° 50′ E). *Asian Journal of Water 2020, Environment and Pollution 2020*, 17(3), 101-109.

18. Zheng, H., Liu, X., Liu, C., Dai, X., & Zhu, R. Assessing contributions to panevaporation trends in Haihe River Basin, China. *Journal of Geophysical Research: Atmospheres* 2009, 114(D24).
19. Piras, G., Pini, F., & Garcia, D. A. Correlations of PM10 concentrations in urban areas with vehicle fleet development, rain precipitation and diesel fuel sales. *Atmospheric Pollution Research* 2019, 10(4), 1165-1179