Analysis of Changes in Air Quality in Major Cities Indonesia During COVID 19 Using Remote Sensing Data

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Abstract. The COVID 19 outbreak has brought many changes to the order of human life. One is affected that life in an urban area. The metropolitan area that is usually crowded with human activity changes drastically to the empty urban. This phenomenon happened because many cities apply the lockdown policy to reduce the spread of COVID-19. This lockdown policy reduces the activity of transportation and industry, causing changes in air quality in the urban area. This study aims to see how much the impact of lockdown policy on air quality in 4 major cities in Indonesia, which is: Jakarta, Medan, Balikpapan, and Makasar. The method that used in this research is using Remote Sensing data by extracting Sentinel Satellite Image data, which produces air quality data, namely data NO2 levels in the air, then comparing the distribution of NO2 in the air between the year 2019 and 2020, and comparing data NO2 concentration in each month in 2020. From the result of the spatial analysis of Sentinel Image Satellite data, during the lockdown policy in the year 2020 was implemented, the NO2 level in Jakarta significantly changed positively, the NO2 levels in the air decreased compared to the year 2019. For cities outside Jakarta, there has been a decrease in NO2, but the change that occurred is not significant. From this research, it can be seen that the lockdown policy during COVID-19 has improved the air quality in major cities in Indonesia.

Keywords: Air Quality, COVID 19, Lockdown, Remote Sensing, Sentinel

1. Introduction

In 2020, the world is hit by a pandemic called by COVID19 virus or Corona Virus. In humans, the coronavirus causes respiratory infections; SARS (Severe Acute Respiratory Syndrome), MERS (Middle East Respiratory Syndrome), and COVID19 are more deadly than the other [1]. Indonesian government programs many programs, including Large-Scale Social Restriction (PSBB) or Lockdown policy. This policy's time is different in each area, it depends on the situation and the local government will. This PSBB is not implemented only in Indonesia; several countries have applied this policy, such as the United States, Spain, and China.

The lockdown policy causes less human movement, and the industrial activities slow down, the amount of car on the road is decreased in the city, and becomes empty, which influences air quality. One of the emotional gases produced by the vehicle is NO2 caused by the burning of fossil fuel [2]. Suppose the NO2 concentration is high, it potential to generated acid rain, cough in young and older people, and cause death [2]. The COVID 19 situation in several areas that is an epicenter of the pandemic, such as
Wuhan, Italy, Spain, and the USA, indicates that the pollution is reduced to 30% [3]. One of the methods to quantify the NO2 in the air is from the remote sensing technology, by using image satellite it can be seen a spatial data of the air pollution. One of the satellites that can be used in the monitoring of air pollution is Sentinel 5P. Sentinel 5P can show the decrease in air pollution in several city in the world [4–6]. In this research, we compare the air quality in several cities in Indonesia by using image satellite. The advantage using image satellite it can show the air quality in large area.

2. Image Satellite Data

Sentinel is satellite image data that can be obtained free of charge. The Sentinel-5P satellite has the main task of monitoring the atmosphere, air, and various gases that affect the air conditions we breathe today through different instruments embedded in the Sentinel-5P Satellite, one of which is called TROPOMI. TROPOMI (TROPOspheric Monitoring Instrument) is an instrument that monitors ozone, methane, aerosols, carbon monoxide, formaldehyde, NO2, and SO2, which are in the atmosphere [7]. The TROPOMI instrument was created in collaboration between the Netherlands Space Office, the Royal Netherlands Meteorological Institute, the Netherlands Institute for Space Research, the Netherlands Organization for Applied Scientific Research, and the Airbus Defense and Space Netherlands. Sentinel 5P already used in several research about the monitoring air quality, such as the temporal characteristic and impact factor of tropospheric NO2 [4], the relationship between pollutants and geographic and demographic data [8], and in the other research show that the data from satellite Sentinel 5P data and in situ measurement have strong and acceptable correlation to monitoring air quality and air pollution [9].

3. Research Method

![Flowchart of Research](image-url)
This research uses the Google Earth Engine software that provides a free-to-use 'planetary-scale platform for Earth science data and analysis. Four cities in Indonesia are selected. Using the Google Earth engine, Sentinel-5P image analysis was carried out in the selected cities, namely Jakarta, Medan, Balikpapan, and Makassar. The reason this city was selected because all of the city is representative of the island in Indonesia, expected to represent the condition in Indonesia. Jakarta Province represent the big city in Java Island, Medan City represent the big city Sumatra Island, Balikpapan represent the Kalimantan Island and Makassar City Represent the Sulawesi Island. By taking this 4 city, this research expected that the result will represent the condition of Indonesia. Processing using the JavaScript programming language that has been provided by the Google Earth engine. With the Sentinel-5P data, atmospheric monitoring capability is carried out to visualize the impact of the COVID-19 lockdown on NO2 levels across Indonesia [10]. If we have seen in figure 1, which shows the research flow chart diagram of the research. From the figure, we can see that after analyzing the Sentinel satellite imagery, which resulted in condition NO2, identification was carried out based on the time of the lockdown policy that was applied in each city. If the lockdown of each town has a different time and later, it will produce an analysis that is unique or different in each city.

4. Result and Discussion

4.1 Indonesia Air Quality

In this analysis, a spatial comparison was made between NO2 conditions before the pandemic in Indonesia, represented by observations in February 2019, April 2019, and June 2019, while observations of NO2 conditions during a pandemic were observed in February 2020, April 2020, and June 2020. Range the amount of NO2 in Indonesia ranges from 0 - 0.0005 mol / m2. It can be seen spatially that the two large islands in Indonesia, namely the island of Java and the island of Sumatra, have a higher concentration of NO2 compared to other islands. This is in line with the fairly high industrial activities and human activities on these two islands because NO2 is one of the waste products from industrial activities and human activities (such as transportation). When viewed in more detail, in Figure 2, namely condition NO2 in February 2019, there is a significant decrease in concentration in the islands of western Sumatra and eastern Java when compared to conditions in February 2020 that shown in figure 3. When related to conditions in February and March that have not implemented a lockdown policy, this can be explained by the rainfall phenomenon, which can be seen in figure 3. In figure 3, a map of rainfall analysis in February 2019 and February 2020 is shown from BMKG. It can be seen that there is an increase in rainfall in 2020. For 2019 in the Jakarta area, the rainfall ranges from 150-200 mm, but for 2020 the amount of rainfall is 400-500 mm. It can be seen clearly in the figure 4, that in February 2020 in several regions of Indonesia there was also an increase in rainfall. With the increase in rainfall in several regions in Indonesia, the air in several major cities in Indonesia is cleaner and reduces the concentration of NO2[11], therefore the decrease in the concentration of NO2 in several areas in February is more due to climatic factors.
Figure 2. Spreading NO2 Concentration on February 2019

Figure 3. Spreading NO2 Concentration on February 2020
If you continue to look at the NO2 condition in April, where the lockdown policy has been implemented in several areas, in Figure 5, the distribution of NO2 in April 2019 has decreased when compared to the condition NO2 in April 2020. You can see that in April 2020 the red color shows concentration NO2 on the island of Java began to disappear. Another interesting thing is seeing the concentration on the western part of Sumatra island. The red color density began to fade in April 2020 when compared to April 2019. For the islands of Kalimantan, Sulawesi and Papua islands, there was also a decrease in concentration, but the decrease was not too significant.

Figure 5. Spreading NO2 Concentration on April 2019
An interesting thing if you look at the conditions in June, if you compare between 2019 and 2020, there is indeed a decrease in the concentration of no2, which is seen in Figure 5 and Figure 6. However, if you compare the concentration of NO2 between June 2020 and April 2020, there is a slight increase in the concentration of No.2 there are Indonesian territories. This is continuous with several lockdown policies in Indonesian cities that have been relaxed or stopped, the start of human activities such as driving or industrial activities affecting the increase in the concentration of NO2 in the air.
When we look at the condition NO2 quantitatively, what is shown in figure 9 shows the value of observation NO2 concentration in several big cities in Indonesia, namely DKI Jakarta, Medan city, Makassar city, Sorong city and Balikpapan City. The x-axis shows the day of observation while the y-axis shows the concentration value NO2. The maximum value of NO2 in 2019 looks around 0.0004 mol / m² but in 2020 it is only around 0.0029 mol / m². From this data, it can be seen that there was a decrease in the concentration of NO2 during 2020 compared to the previous year, namely 2019. From this graph, it can be seen that the DKI Jakarta province has the highest concentration of NO2 in the observed locations, namely the city of Jakarta then Medan, while the city of Makassar is the city of Sorong and the city of Balikpapan has a fairly similar concentration. In general, in the territory of Indonesia, that the lockdown policy issued by several provinces or city districts has affected the reduction in concentration of NO2 in Indonesia.

Figure 9. NO2 Concentration Value in several cities in Indonesia

4.2 Major Cities in Indonesia

4.2.1 DKI Jakarta Province

In figure 10 shows the spatial distribution of concentration NO2 in the province of DKI Jakarta in February 2019, February 2020 to September 2020. Spatially seen from the processed sentinel satellite images, there is a buildup of NO2 concentrations marked in red in several locations, for February of the year In 2019, it can be seen that number 2 marked in red is evenly distributed throughout the DKI Jakarta province, for the conditions in 2020, it can be seen that there is a decrease in concentration, which is seen only a few dots are red and others are yellow and orange, only seen in May. As previously explained, it can be seen in Figure x, the condition of decreasing concentration of NO2 in the air in February and March is more caused by climatic factors, namely the rainfall in February in several cities in Indonesia increases.
For April, the lockdown began to apply on April 10, but spatially there has not been any change towards the addition of NO2 concentrations in the Jakarta area, this can be interpreted as human movement or activity in DKI Jakarta Province in February which is still busy. However, for April and May 2020, there was a decrease in the concentration of no2 in the air which can be seen by the disappearance of the red colour, which indicates the high concentration of NO2 in the city of Jakarta. It can be seen that with the implementation of a comprehensive lockdown, there has been a decrease in the concentration of No.2 in the province of Jakarta. If we look at the distribution of no2 in August, it starts to return to a high level, this is in line with the lifting of the total lockdown and entering into a transitional lockdown period. In this transitional lockdown condition, office and industrial activities are running almost as usual, marked by the appearance of red colours in June, July and August.

Figure 10. NO2 concentration in DKI Jakarta Province Form Feb 2019 to Aug 2020
In DKI Jakarta Province, the second lockdown phase was carried out, namely on September 14, 2020 to October 11, but it can be seen in Figure 11 that the concentration of NO$_2$ in the Jakarta area does not seem to have decreased, even the concentration in October can be seen spatially the red area looks more widespread, this indicates that there is an increase in the no2 construction.

If seen in figure 12, it can be seen that in the first 3 months of the year in the early conditions of 2020, the red graph showing the concentration of no2 in 2020 is below the blue line which shows the concentration of no2 in 2019. But in the second month day 30 to day 100, number 2 in 2020 is greater than in 2019. The factor for the decrease in concentration no2 is more caused by high rainfall in the city of Jakarta. However, it can be seen that on the 130th day, namely the 10th of April to the 4th day of June, namely the 184th day, it can be seen in the graph that the concentration of no2 in 2020 is generally seen to be lower. This period is the PSBB period in the city of Jakarta, quantitatively as seen in the picture, in this phase 1 period, there was a decrease in the concentration of No2 in Jakarta. After the total PSBB is carried out, it is followed by a transition lockdown policy. It can be seen that from June 5 to September 13, which is day 185 to day 260, the condition no2 is almost the same as in 2019, as well as the second phase of PSBB, no2 is almost the same as the previous year.
4.2.2 Medan District

When viewed spatially in the city of Medan, the comparison of NO2 concentrations in February 2019 with February 2020, it is seen that there has been a decrease in NO2 concentrations in Medan City, in we see back in the figure 2, indeed in Medan there is an increase in rainfall which can clean the concentration of NO2 in the air. If we look at the distribution of no2 in April, the concentration of no2 in Medan city is higher in the south. The lockdown policy in the city of Medan was carried out on April 30 to May 14, if seen in the distribution no2 in May, there was indeed a decrease in concentration no2 in the city of Medan, but when viewed in June and July, there is an increase in Back which is shown by the appearance of orange colours concentrated in the city of Medan, it can be seen in figure 13. From the conditions described above, it can be seen that spatially there is a significant relationship between the PSBB policy and the air conditions in the city of Medan, in the month when the lockdown is applied, spatially there is a decrease in the concentration of NO2 in the air.

When viewed quantitatively, it can be seen in figure 14, on the graph there is a decrease in concentration NO2 in 2020 when compared to the concentration in 2019. It can be seen that the maximum value of concentration NO2 throughout 2019 is close to 0.000175 mol / m2, while in 2020, the value The maximum concentration of NO2 in Medan is only close to 0.000125 mol / m2. If you look at the period of 30 paril to 14 May, namely from 120 to 134, indeed the concentration of no2 in Medan in 2020 is smaller than the concentration of No.2 in 2019.

Figure 13. NO2 concentration in Medan City Form February 2019 and July 2020
4.2.3 Makasar District

For the Makassar area, if you look at the spatial comparison of the concentration of No.2 in 2019 and 2020, there is not much difference. This is in line with the conditions shown in figure 15, it can be seen that the conditions of rainfall in Makassar in February 2020 are almost the same as February 2019. In March, there was a significant increase with the concern of the orange color in Makassar city in March 2020 which showed its height. concentration no2 in March. The PSBB policy in the city of Makassar runs from 24 March to 7 May, this seems to have a very significant impact on the concentration no2 when viewed spatially, it can be seen that April 2020 experienced a decrease in concentration no2 in the city of Makassar, but immediately at the beginning of May the PSBB policy was revoked again, No2 condition in Makassar City is back high.
When viewed in a quantitative manner, which is shown in Figure 16, it can be seen that there is no significant difference between the concentration of No.2 in 2019 and 2020. It can be assumed that although there has been a slight decrease, it is because in 2019 the maximum concentration of No.2 in Makassar is only around 0.0006 mol/m² which is relatively low compared to other big cities in Indonesia, so the difference is not too significant.

![Figure 16. NO2 Concentration Value in Makasar City](image)

### 4.2.4 Balikpapan District

In Balikpapan city, there is no lockdown policy that implemented by the major cities, to prevent the spread of COVID 19 in this city, the major online close all the entertainment venue form 22 March to 5 April. If we see the map in the figure 17. There is no big different between the no2e concentration on februari 2019 and februari 2019. But if we seen on the map that show the concentration in march and April, there area a little decreasing for the concentration of no2 in both month. But when it come to may, the maps show that the orange colour that indicate of the concentration of no2 that high is appears again. This phenomena shows that there is an impact of change of no2 concentration when the policy of prevent the covid 19 is done. The figure 18 show the comparison of concentration no2 in 2019 and 2020 in Balikpapan City. if both years is being compered, there a lot of fluctuative comparison result,because the result in several month is higher but in several month the concentration of no2 in year 2020 lower than year 2019.

![Figure 17. NO2 concentration in Balikpapan City Form February 2019 and June 2020](image)
Figure 18. NO2 Concentration Value in Balikpapan City

5. Conclusion

From the result of observation of NO2 concentration in several cities in Indonesia by using remote sensing, we can conclude that in Indonesia in general, there is a change of NO2 concentration when the policy lockdown is being applied. From the spatial observation, we can see that in two big islands in Indonesia, which is Java and Sumatera Island, the change is very clearly visible. If we see the data in the early years of 2020, there is a decrease in concentration when compared with data in 2019. If we analyze the rainfall data in the early year 2020, several areas in Indonesia have an enhancement of rainfall. The amount of rainfall that occurs is above the average. This situation means that the rainfall washes the no2 in the atmosphere, so the concentration of no2 in the air is decreasing [12]. The orange color that shows in early years, became faded when the policy lockdown is applied. It clearly being seen in Province DKI Jakarta. The high concentration of no2 before the lockdown policy became faded when the lock down policy is being applied. If we compare it with another cities in Indonesia, there an decreasing of no2 concentration but the amount is not as big as in DKI Jakarta Province. As the result we can have a conclusion that, the remote sensing data that we use wich is Sentinel 5P image satellite can capture the fenomena of the change of NO2 concentration in the air during the lock down policy in Indonesia[4–6]. The impact of lockdwon policy in Indonesia, make the NO2 concentration is decreasing, but when the lockdown policy is being stopped, the NO2 concentration is rise again.

6. Acknowledge

The author thanks God Almighty because thanks to His grace the author can finish this journal. In addition, the author also thanks Dr. Ina Helena Agustina who has facilitated this activity. All authors of this article contribute equally and each as a major contributor.

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