Analysis of Air Quality During the COVID-19 Pandemic Using Remote Sensing Data in DKI Jakarta

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ABSTRACT

The distribution of air pollution in an area can be determined by using remote sensing data. This study aims to (1) identify and inventory the parameters determining the level of air quality; (2) implementing a number of algorithms to measure air quality using remote sensing data; and (3) evaluate the results of air quality calculations from remote sensing data with in-situ data in the field. The map-making process is carried out by processing Landsat 8 OLI/TIRS image data for 1 year starting from January to December 2020 in DKI Jakarta and by applying a number of algorithms. The algorithms used in determining air quality include: the algorithm developed by Othman to measure the PM_{10} concentration, the Somvashi algorithm to measure the CO concentration, the SO_2 concentration determined by applying the Hasan algorithm, and the algorithm developed by Alserory to calculate the NO_x concentration in the air. Air quality parameters that can be known by using Landsat 8 OLI/TIRS satellite imagery are PM_{10}, CO, SO_2, and NO_x. These results are then correlated with the SPKU belonging to the DKI Jakarta Environment and Forestry Service. The PM_{10} parameter has a correlation of -0,13, 0,26, -0,72, -0,25 and -0,18. The next parameter is SO_2 with correlation values -0.02, 0,3, -0,6, -0,4 and -0,3. As for the CO parameter, it cannot do the correlation test because the value of the satellite image processing results is 1. -0,39, -0,34, -0,31, -0,45, and -0,53 are the correlation values for the NO_x parameter. Based on these results, it is necessary to develop a new algorithm and make adjustments to certain areas to analyze air quality, so that it can produce reliable and accountable information on air quality.

INTRODUCTION

Based on Peraturan Pemerintah Republik Indonesia Tahun 1999 Nomor 41 Tentang Pengendalian Pencemaran Udara, “Air pollution is the entry or inclusion of substances, energy, and/or other components into ambient air by human activities, so that the quality of ambient air drops to a certain level which causes ambient air to be unable to fulfill its function”. Engineer’s Joint Council in Wang et al., (2004) defines air pollution as “the presence of one or more contaminants such as dust, gas, mist, odor, smoke or vapor in the amount, characteristics and duration in the outdoor atmosphere that endanger and interfere with the comfort of human life and other living creatures and harm property”.

The increasing number and density of the population as well as the status of DKI Jakarta Province as the economic centre in Indonesia are the causes of declining air quality in DKI Jakarta Province. Land transportation is the largest contributor to air pollution in DKI Jakarta, which is as much as 75%. In addition to land transportation, air pollution is also contributed by industrial combustion as much as 8%, domestic combustion as much as 8%, and electricity and heating plants as much as 9% (Dinas Lingkungan Hidup Provinsi DKI Jakarta, 2020). Data from Ditlantas Polda Metro Jaya, mention that the number of motorbikes in DKI Jakarta continues to increase by 5,35% every year with the number of motorbikes in 2016 being 18.006.404 units (Badan Pusat Statistik DKI Jakarta, 2018)also known as bone marrow-derived mesenchymal stem cells.

Air pollution refers to physical, chemical or biological substances that enter the atmosphere, cause damage or discomfort to the human body or other organisms, or damage the natural environment (Gurjar et al., 2010). There are several air pollutants that are often found in cities, including: carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x) which consists of 2 gases, are SO_2 and SO_3. PM is a source of pollution by suspended particles originating from natural events such as dust or fine sand carried by the wind, due to volcanic eruptions that throw ash and volcanic materials. Meanwhile, most of those sourced from human activities come from burning coal, industrial processes, forest fires, and the results from vehicle exhaust gases (Prabowo & Muslim, 2018).

During the COVID-19 pandemic, several cities that implemented social distancing, physical distancing and PSBB policies were able to suppress and reduce air pollution caused by motorized vehicles. Anticipatory efforts to reduce the number of corona virus sufferers in Indonesia have been carried out in all regions. It is hoped that the lockdown can help prevent the spread of the corona virus from one area to another, so that people in areas who have not been infected with this virus can be avoided (Indriya, 2020).

Restrictions on human activities during the COVID-19 pandemic and the cessation of various economic activities including some industrial sectors have all contributed to the reduction of global emissions. The Center for Research on Energy and Clean Air (CREA) announced that due to the implementation of COVID-19 quarantine measures in many countries, global CO_2 emissions have been reduced by 17%. At the height of the lockdown, nearly half (43%) of global emission reductions came from the transportation and industrial sectors, especially motor vehicles and commercial manufacturing plants (Suryani, 2020).

In China, emission levels were reduced by 25% at the start of the year, when people were ordered to stay at home. Factories closed and coal use at China's 6 largest power plants fell by 40 percent. The proportion of days with "good air quality" increase 11,4% over the same time last year in 337 cities across China. In Europe, satellite imagery shows nitrogen dioxide (NO2) emissions fading over northern Italy. The same phenomenon occurs in Spain and England (Henriques, 2020).

Remote sensing technology has now been widely used by various groups from various backgrounds in the scientific field. This is because remote sensing data provides information about objects and phenomena that occur through analysis of satellite data covering a wide, continuous, and accurate area without the need for direct contact with the object or phenomenon(Lillesand et al., 2004). Satellite observations can provide a complete survey of the city; indicate the main sources and distribution of pollution; help determine the degree of pollution reduction, and determine the relationship between city characteristics and the distribution of air pollution. Another study reveals the possibility of establishing a correlation between air pollution and satellite imagery (Narashid & Wan Mohd, 2010). For example, research by Dewi et al., (2014) using Landsat-8 satellite imagery to get an overview of the PM10 distribution in Bandung. A similar study was also carried out by Fernández-Pacheco et al., (2018) conducted research related to the estimation of PM distribution using Landsat 5 and Landsat 8. Sentinel-5 and MODIS images were used by Safarianzengir et al., (2020) to investigate spatially and temporally and analyze air pollution (carbon monoxide, CO) in Iran.

Based on Peraturan Pemerintah Republik Indonesia Tahun 1999 Nomor 41 Tentang Pengendalian Pencemaran Udara, "ambient air is free air on the earth's surface in the troposphere which is within the jurisdiction of the Republic of Indonesia which is needed and affects the health of humans, living things and other elements of the environment". It is said to be dangerous if these elements have exceeded the ambient air quality standards. Ambient air quality standard itself can be interpreted as a measure of the limit or level of substances, energy, and/or components that exist or should be present and/or pollutant elements whose presence is tolerable in ambient air. The following is a measure of the national ambient air quality standard. The national ambient air quality standard value is presented in the form of the Air Pollutant Standard Index (ISPU) as seen in the following table 1.

Table 1. ISPU number range category

Category	Color Status	Number Range
Good	Green	1 – 50
Moderate	Blue	51 – 100

Unhealthy	Yellow	101 – 200
Very unhealthy	Red	201 – 300
Hazardous	Black	≥301

The general objective of this research is to analyze the air quality in DKI Jakarta based on the parameters that determine the level of air quality that already exists by applying remote sensing data. To achieve this main goal, more specific objectives are needed, including identifying and taking inventory of the parameters determining the level of air quality, applying a number of algorithms to measure air quality using remote sensing data and evaluating the results of air quality calculations from remote sensing data with in-situ data in the field.

DATA AND METHODOLOGY

This section describes in detail about the research conducted, including the location of the research, the data used, and the methodology applied.

Research Location

The location of this research is in DKI Jakarta which is astronomically located between 6^0 12' South latitude (LS) and 106^0 48' East longitude (BT) with land area according to SK Gubernur Nomor 171 tahun 2007 is 662,33 km^2 and 6977,5 km^2 is the area of the ocean. Administratively, DKI Jakarta is divided into 5 municipalities and 1 administrative district, are Jakarta Pusat, Jakarta Utara, Jakarta Barat, Jakarta Selatan, Jakarta Timur and District Administration of Kepulauan Seribu (Badan Pusat Statistik DKI Jakarta, 2020).

DKI Jakarta, which is the capital of the Republic of Indonesia as well as a business center and government center, has a fairly dense population. The total population of DKI Jakarta in 2013 was 9.969.948 million/person and an increase of 497.681 people in 2019. This is directly proportional to the increase in the number of motorized vehicle ownership which increases every year. In 2019, the number of motorized vehicles in DKI Jakarta was 20.965.708 units. Based on this, it can be concluded that the number of motorized vehicles is 2 times more than the number of existing residents. The large number of motorized vehicles in the capital, triggers the increase in air pollution in the capital.

The level of air pollution, including the concentration of pollutants in an area, can be determined using the SPKU. SPKU, also known as the Air Quality Monitoring System (AQMS) is a tool used to monitor air quality in an area and is informed as an Air Pollution Standard Index (ISPU) which is reported every 24 hours. There are 5 SPKUs spread across DKI Jakarta, namely:

Table 2. The location of SPKU in DKI Jakarta

Station Name	Station Location	Station Code
SPKU Bundaran HI	Kota Jakarta Pusat	DKI1
SPKU Kelapa Gading	Kota Jakarta Utara	DKI2
SPKU Jagakarsa	Kota Jakarta Selatan	DKI3
SPKU Lubang Buaya	Kota Jakarta Timur	DKI4
SPKU Kebon Jeruk	Kota Jakarta Barat	DKI5

For more details can be seen in Figure 1.

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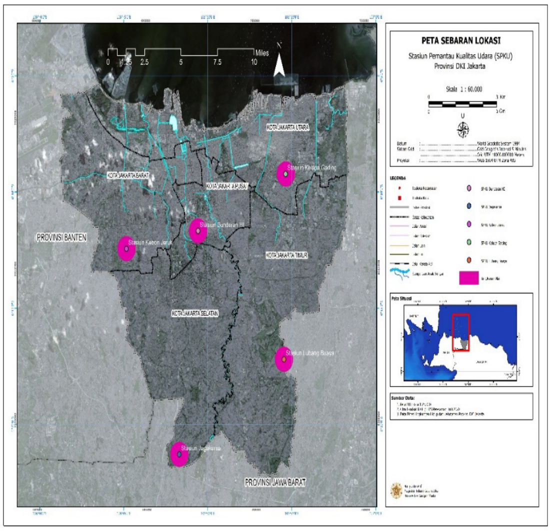

Figure 1. Distribution of SPKU locations in DKI Jakarta

Data and Methodology

The data used includes air quality data for 1 year starting from January 2020 to December 2020 which includes CO, SO_2, NO_x and PM_{10} data as well as Landsat 8 OLI/TIRS satellite imagery in the same month and year. Processing of Landsat 8 OLI/TIRS satellite image data using the ArcGis 10.8 application. The following is a description of data processing.

Radiometric correction

Radiometric correction is performed to correct and eliminate distortions as a result of the position of the sun. This is because the position of the sun and the earth always changes depending on the time of recording and the location of the object being recorded. The digital number (DN) conversion process to the ToA radiance value uses the formula, namely (Department of the Interior U.S. Geological Survey, 2016)

$$L_\lambda = M_L Q_{cal} + A_L \quad (1)$$

L_λ = *ToA spectral radiance* (Watts/(m^2 * srad * μm))
M_L = *RADIANCE_MULT_BAND_x*, where x is the band number
Q_{cal} = *RADIANCE_ADD_BAND_x*, where x is the band number
Q_{cal} = *digital number* (DN)

Meanwhile, the digital number (DN) conversion process to the ToA reflectance value uses the formula, namely (Department of the Interior U.S. Geological Survey, 2016)

$$M \quad \rho \quad (2)$$

M_ρ = *REFLECTANCE_MULT_BAND_x*, where x is the band number
A_ρ = *REFLECTANCE_ADD_BAND_x*, where x is the band number
Q_{cal} = *digital number* (DN)
θSE = Sun elevation

Extraction of PM_{10} and CO information

One of the algorithms that can be used to extract PM_{10} information is the algorithm developed by Othman et al., (2010) The form of this algorithm is

$$PM_{10} = 396R_{\lambda 2} + 253R_{\lambda 3} - 194R_{\lambda 4} \quad (3)$$

PM_{10} = aerosol particulat (µg/m^3)
$R_{\lambda 2}$ = reflectance value from red band
$R_{\lambda 3}$ = reflectance value from green band
$R_{\lambda 4}$ = reflectance value from blue band

Information about CO can be extracted using the algorithm developed by Somvanshi et al., (2020). The following is the form of the equation that was successfully developed.

$$CO = 83.659 + \left(-0.427 * R_{\lambda 3}\right) + \left(0.22 * R_{\lambda 4}\right) + \left(-0.461 * R_{\lambda 7}\right) \quad (4)$$

CO = carbon dioxide (mg/l)
$R_{\lambda 3}$ = reflectance value from green band (*green*)
$R_{\lambda 4}$ = reflectance value from blue band (*blue*)
$R_{\lambda 7}$ = reflectance value from *short wave infrared* (*SWIR*) band

Extraction of SO_2 and NO_x information

Before extracting SO_2 and NO_x information, the image data must be converted to Brightness Temperature values to obtain the effective temperature that will be used for determining air quality and NOx. The conversion process from the ToA radiance value to the TIRS band data uses the thermal constants contained in the metadata file. The similarities are (Department of the Interior U.S. Geological Survey, 2016).

$$T = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda} + 1\right)} \quad (5)$$

T = *At-satellite brighteness temperature* (K)
L_λ = *ToA spectral radiance* (Watts/(m^2 * srad * µm))
K_1 = K1_CONSTANT_BAND_x, where x is *thermal band*
K_2 = K2_CONSTANT_BAND_x, where x adalah *thermal band*

NO_x information extraction in this study used an algorithm developed by Alseroury (2015). The following is the form of the algorithm used

$$NO_x = 0.3908x + 163.88 \quad (6)$$

x = ***Brightness Temperature*** value (^{0}C)
NO_x = the value of NO_x is looking for (µg/m^3)

Meanwhile, to extract SO_2 information, the algorithm developed by Hasan et al., (2014)2014 using NOVA device to measure SO2 concentrations. The research showed a good correlation between groundbased measurements and satellite data with (R2=0.48 for band 11 and R2= 0.52 for band 10. The following is the form of the algorithm of band 10 used.

$$SO_2 = 0.00117x^3 - 0.3282x^2 + 2.837x - 6.4733 \quad (7)$$

x = *Brightness Temperature* value (^{0}C)
SO_2 = the value of SO_x is looking for (ppm)

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Conversion of ISPU parameter concentration values

The parameter concentration values at ISPU have not shown the actual air quality standard values but must first be converted to the equation below in order to be categorized based on table 3.

$$I = \frac{(I_a - I_b)}{(X_a - X_b)}(X_x - X_b) + I_b \tag{8}$$

I = ISPU
I_a = ISPU upper limit
I_b = ISPU lower limit
X_a = Upper limit ambient concentration (μg/m^3)
X_b = Lower limit ambient concentration (μg/m^3)
X_x = Real ambient concentration measurement results (μg/m^3)

Table 3. ISPU value conversion

ISPU	0 – 50	51 – 100	101 – 200	201 – 300	≥300
24 hours particulate matter (PM_{10}) μg/m^3	50	150	350	420	500
24 hours sulfur dioksida (SO_2) μg/m^3	52	180	400	800	1200
24 hours karbon monoksida (CO) μg/m^3	4000	8000	15000	30000	45000
24 hpurs nitrogen dioksida (NO_2) μg/m^3	80	200	1130	2260	3000

Data correlation

Data correlation is the step taken to test the suitability of the data resulting from computer processing with the actual data (data in the field). The strength of the relationship is expressed in the correlation coefficient which is often abbreviated as r. While the direction of the relationship is indicated by a positive or negative relationship. In correlation all variables have the same position, and there is no variable that affects (independent) or variable that is influenced (dependent). One of the most used correlation tests is the Pearson correlation test. The form of the equation is as follows.

$$r = \frac{n\sum x_i y_i - \sum x_i y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\,.\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \tag{9}$$

Table 4. Correlation values.

Correlation values	Relationship Level
0,00 – 0,119	Very low
0,20 – 0,399	Low
0,40 - 0,599	Moderate
0,60 – 0,799	Strong
0,80 – 1,000	Very strong

RESULTS AND INTERPRETATION

The air quality of an urban area can be analyzed and visualized using remote sensing technology. In this study, the air quality standard parameters analyzed include PM_{10}, SO_2, CO, and NO_x using a number of existing algorithms.

Parameter PM_{10}

The PM_{10} concentration value was generated through analysis of Landsat 8 OLI/TIRS satellite imagery and utilizing an algorithm developed by Othman et al., (2010). The average value of the concentration generated from the algorithm is in the range of values of 65,53 – 186,16 μg/m³. Based on the results of the conversion of the PM_{10} concentration value to the ISPU value, it can be seen that all SPKUs are in the moderate category with their respective values, are 76, 66, 62, 65, and 65. The distribution can be seen in the image below. Spatially, the distribution of PM_{10} in DKI Jakarta shows a different visual color every month. The range of PM_{10} concentrations in January was 56,72 – 572,66 μg/m³ and continued to decline until April 2020 with recorded PM_{10} concentrations of 15,95 – 205,48 μg/m³. The decrease in the concentration value is the impact of the enactment of PSBB in DKI Jakarta on April 10, 2020. This decision was taken to reduce the spread of the community and areas infected with COVID-19. As an indirect impact of the enactment of this regulation, the PM_{10} level has also been drastically reduced due to the lack of functioning modes of transportation. The results of image analysis show a downward trend in the value of PM_{10} concentration in DKI Jakarta province in April 2020 and an increase in June and the following month which is the transitional PSBB period. The increase was not as significant as the PM_{10} concentration level at the beginning of 2020.

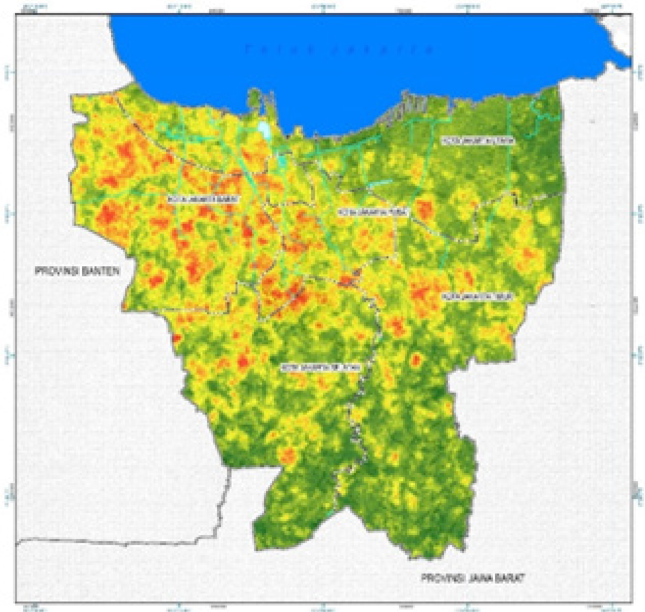

Figure 2. PM_{10} distribution in DKI Jakarta

Parameter SO_2

The concentration value of the SO_2 parameter was also generated with the same treatment as the PM_{10} value, but by changing and adjusting the algorithm used by utilizing the algorithm developed by Hasan et al., (2014)2014 using NOVA device to measure SO2 concentrations. The research showed a good correlation between groundbased measurements and satellite data with (R2=0.48 for band 11 and R2= 0.52 for band 10. The results of the algorithm produce a range of numbers from 7,80 – 20,80 ppm which when converted to μg/m³ units, the resulting range of values is 20,36 – 54,29 μg/m³. The resulting ISPU scores are in the good category, with respective scores of 35, 27, 27, 29 and 39.

The lowest known concentration value is 2,07 ppm recorded on March 21, 2020 at ISPU DKI5. This value is then converted to units of μg/m³ by multiplying it by a value of 2,61 (1 ppm SO_2 = 2,61 μg/m³). So that the concentration value obtained is 5,4 μg/m³. ISPU DKI2 recorded a fairly high SO_2 concentration value of 37,35 ppm or equivalent to 97,48 μg/m³ on June 25, 2020. Similar to PM_{10} distribution, the spatial distribution of SO_2 in DKI Jakarta province also shows different visual colors in each area. the month. The spatial distribution in January 2020 has a concentration value range between 3,55 – 27,20 ppm and continues to increase in maximum value until October 2020. There was a spike in the SO_2 concentration value in February 2020 to 5,57 – 34,63 ppm or an increase of 2 times when compared to the previous month. The decrease in the value of

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SO_2 concentration occurred again in November and December 2020 which is the time for the long Christmas and New Year holidays so that the volume of vehicles and a number of modes of transportation is reduced. This causes the value of SO_2 concentration to decrease.

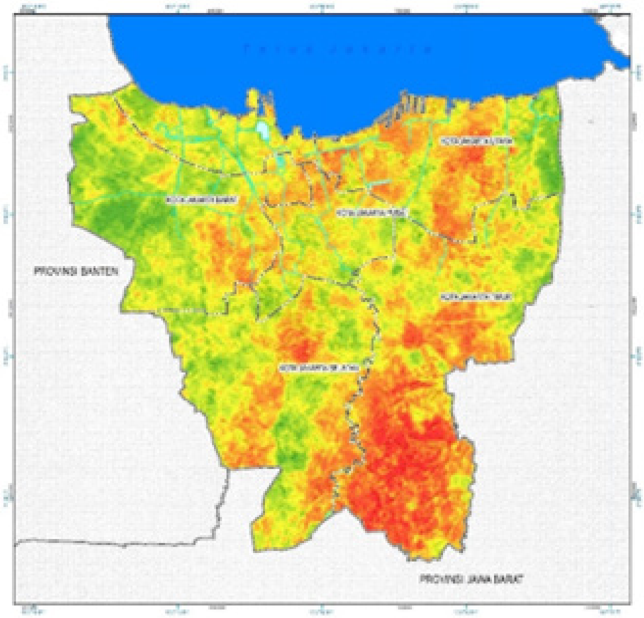

Figure 3. SO_2 distribution in DKI Jakarta

Parameter CO

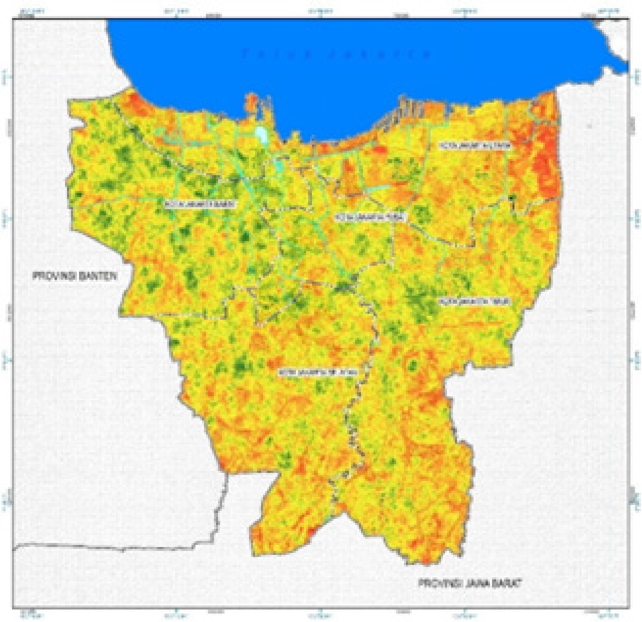

Figure 4. CO distribution in DKI Jakarta

Based on the results of the analysis using the algorithm proposed by Somvanshi et al., (2020) the average concentration value produced is 83,31 – 83,60 mg/l. This value is obtained from the results of image mosaicking from January to December 2020. In order to comply with the provisions Peraturan Pemerintah Republik

Indonesia Tahun 1999 Nomor 41 Tentang Pengendalian Pencemaran Udara , this value must be converted to μg/m^3, so that the resulting value range is ±119 μg/m^3. In general, the value of CO concentration that has been processed and analyzed shows a value that is not diverse or homogeneous. This value is at 83 mg/l or equivalent to 58 μg/m^3 (1 mg/l CO = 1 ppm CO = 0,7 μg/m^3) which if converted to the ISPU value is 1. The concentration value is found in all stations during the period January to December 2020.

The significant difference in values between the field data and the results from satellite image processing shows that there is a mismatch of the algorithm developed by Somvanshi et al., (2020). This discrepancy is caused by several causes, including differences in geographical location, causing differences in weather and climate factors. The research location of Somvanshi et al., (2020) is in Delhi, which is the capital city of India. India is known to have 4 distinct seasons, where the air temperature will be very hot in summer (April – July) with an average air temperature of 25 ^{0}C to 45 ^{0}C and will be very cold in winter (December – January) with an average air temperature of - average 22 ^{0}C to 5 ^{0}C. Apart from geographical factors, other factors also affect the people and the number of factory establishments in the city.

Parameter NO_x

The average concentration of NO_x in each SPKU in DKI Jakarta is in the unhealthy category. This category is generated from the application of the algorithm developed by Alseroury (2015). Based on this algorithm, the average NO_x concentration value is 168,86 – 172,80 μg/m^3. There is a very significant difference in value between the data in the field and the results of processing using satellite imagery. The value obtained from the results of satellite image processing shows that the pollutant conditions in the DKI Jakarta province are in the unhealthy or yellow category. This is evidenced by the value of the NO_x concentration in this region which is at a value of ±183 μg/m^3.

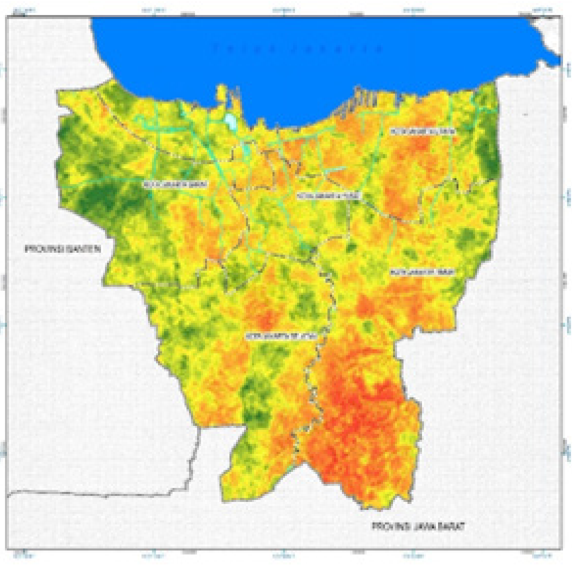

Figure 5. NO_x distribution in DKI Jakarta

As with the previous parameters, the NO_x parameter using the algorithm developed by Alseroury (2015) shows different results. The amount of concentration value generated by satellite imagery is influenced by several determinants of the coefficient, one of which is the geographical location of the research area. The research area selected by Alserory (2015) is a desalination power plant located in Jeddah city. Judging from the location of this power plant, it will be greatly influenced by seasonal climatic conditions. In winter, the air temperature in the area is 12 ^{0}C to 25 ^{0}C with humidity between 65% - 75%. Meanwhile, in summer the average air temperature is 25 ^{0}C to 45 ^{0}C and the humidity is 50% - 55% on average. Meteorological conditions that are very striking from this place are the average annual rainfall of only 3,2 mm or relatively low so that the existing air pollutants tend to settle in the area. Air temperature, humidity and wind speed are some of the determining factors for the presence or absence of pollutants in an area. The coefficient value of 183 g/m3 in the equation developed by Alseroury (2015) is more or less influenced by the surface temperature conditions of the area as evidenced by the correlation between the surface temperature of satellite image processing (LST) and air pollutant data obtained directly.

CONCLUSION

Air pollution that occurs in urban areas has become a serious and difficult problem to deal with. Polluted air can cause serious health problems including death, cardiovascular disease, changes in lung function and asthma attacks. Remote sensing satellite images such as Landsat 8 OLI/TIRS are able to estimate changes in air quality in the DKI Jakarta. This research shows that there is a correlation between in situ data and several algorithms that have been developed previously, although the correlation is negative. The PM_{10} parameter has a correlation of -0,13 for DKI1, DKI2 of 0,26, DKI3 of -0,72, DKI4 of -0,25 and DKI5 of -0,18. The next parameter is SO_2 with correlation values of -0,02, 0,3, -0,6, -0,4 and -0,3 for each SPKU. As for the CO parameter, the correlation test cannot be carried out because the value of the satellite image processing results is 1. -0,39, -0,34, -0,31, -0,45, and -0,53 is the correlation value for the NO_x parameter in each SPKU spread in DKI Jakarta.

The results of this research indicate that air pollution can be mapped using satellite imagery data to cover a large area. Further research by improving and improving the mathematical model used and the statistical analysis used.

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REFERENCES

Alseroury, F. A. (2015). *The Effect of Pollutants on Land Surface Temperature Around Power Plant. 11*, 17–21.

Badan Pusat Statistik DKI Jakarta. (2020). Provinsi DKI Jakarta Dalam Angka 2020. *Provinsi DKI Jakarta Dalam Angka 2020.*

Badan Pusat Statistik DKI JAKARTA. (2018). Statistik Transportasi Dki Jakarta 2018. *Katalog BPS*, *1*, 68. https://doi.org/8301007.31

Department of the Interior U.S. Geological Survey. (2016). Landsat 8 Data Users Handbook. *Nasa*, *8*(June), 97. https://landsat.usgs.gov/documents/Landsat8DataUsersHandbook.pdf

Dewi, N., Hernawati, R., & Darmawan, S. (2014). *Identification of PM10 Air Polution Distribution Using Satellite Landsat Images in Bandung, Indonesia. 41*, 61–68.

Dinas Lingkungan Hidup Provinsi DKI Jakarta. (2020). *Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah Provinsi DKI Jakarta Tahun 2020. 2507*(1), 1–9.

Fernández-Pacheco, V. M., López-Sánchez, C. A., Álvarez-Álvarez, E., López, M. J. S., García-Expósito, L., Yudego, E. A., & Carús-Candás, J. L. (2018). Estimation of PM10 Distribution using Landsat5 and Landsat8 Remote Sensing. *Proceedings*, *2*(23), 1430. https://doi.org/10.3390/proceedings2231430

Gurjar, B. R., Molina, L. T., & Ojha, C. S. P. (2010). Air Pollution: Health and Environmental Impacts. In *Air Pollution: Health and Environmental Impacts.* https://doi.org/10.1201/EBK1439809624

Hasan, G., Kubaisy, M. A. Al, Nahhas, F. H., Ali, A. A., Othman, N., & Hason, M. M. (2014). Sulfur Dioxide (SO2) Monitoring Over Kirkuk City Using Remote Sensing Data. *Journal of Civil & Environmental Engineering*, *04*(05), 2–7. https://doi.org/10.4172/2165-784x.1000155

Henriques, M. (2020, April 7). *Virus corona: Dampak "lockdown" pada penurunan polusi, akankah selamanya? - BBC News Indonesia.* 7 April 2020. https://www.bbc.com/indonesia/vert-fut-52194438

Indriya, I. (2020). Konsep Tafakkur Dalam Alquran Dalam Menyikapi Coronavirus COVID-19. *SALAM: Jurnal Sosial Dan Budaya Syar-I*, *7*(3). https://doi.org/10.15408/sjsbs.v7i3.15048

Lillesand, T. M., Kiefer Ralph W, & W, C. J. (2004). *-[T-M-Lillesand]-Remote-Sensing-and-Image-Interpret pp 1-105.pdf* (pp. 1–2).

Narashid, R. H., & Wan Mohd, W. M. N. (2010). Air quality monitoring using remote sensing and GIS technologies. *CSSR 2010 - 2010 International Conference on Science and Social Research*, *Cssr*, 1186–1191. https://doi.org/10.1109/CSSR.2010.5773713

Othman, N., Mat Jafri, M. Z., & San, L. H. (2010). Estimating Particulate Matter Concentration over Arid Region Using Satellite Remote Sensing: A Case Study in Makkah, Saudi Arabia. *Modern Applied Science*, *4*(11). https://doi.org/10.5539/mas.v4n11p131

Peraturan Pemerintah Republik Indonesia Tahun 1999 Nomor 41 Tentang Pengendalian Pencemaran Udara. (1999). Peraturan Pemerintah Republik Indonesia Tahun 1999 Nomor 41 Tentang Pengendalian Pencemaran Udara. *Peraturan Pemerintah No. 41 Tentang Pengendalian Pencemaran Udara*, *1*, 1–5. https://doi.org/10.1016/j.aquaculture.2007.03.021

Prabowo, K., & Muslim, B. (2018). *Bahan Ajar Kesehatan Lingkungan: Penyehatan Udara.* Kementerian Kesehatan Republik Indonesia. Pusat Pendidikan Sumber Daya Manusia Kesehatan, Badan Pengembangan dan Pemberdayaan Sumber Daya Manusia Keshatan.

Safarianzengir, V., Sobhani, B., Yazdani, M. H., & Kianian, M. (2020). Monitoring, Analysis and Spatial and Temporal Zoning of Air Pollution (Carbon Monoxide) using Sentinel-5 Satellite Data for Health Management in Iran, Located in the Middle East. *Air Quality, Atmosphere and Health*, *13*(6), 709–719. https://doi.org/10.1007/s11869-020-00827-5

Somvanshi, S. S., Vashisht, A., & Chandra, U. (2020). Delhi Air Pollution Modeling Using Remote Sensing Technique. *Handbook of Environmental Materials Management*, *2*(May), 707–713. https://doi.org/10.1007/978-3-319-58538-3

Suryani, A. S. (2020). Dampak Pandemi COVID-19 Terhadap Lingkungan Global. *Bidang Kesejahteraan Sosial*, *XII*(13), 13–18. http://yayasanpulih.org/2020/04/dampak-pandemi-COVID-19-bagi-perempuan/

Wang, L. K., Pereira, N. C., & Hung, Y. (2004). *Air Pollution Control Engineering* (Vol. 1).