Overview of the Air Pollution Standard Index and Associated Health Risk in DKI Jakarta during the 2019 Dry Season

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Abstract. In 2019, Jakarta received a bad image as the city with the worst air quality in the world. The purpose of this study is to describe the status of air quality in DKI Jakarta based on the national ambient air quality standard (NAAQS) and its impact on health based on the Air Pollution Standard Index (PSI). This study uses data on the concentration of particulate matter with aerodynamic diameter < 10 µm (PM10), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and nitrogen dioxide (NO2) based on measurements by the Provincial Environmental Laboratory (LLHD) DKI Jakarta in five locations of Air Quality Monitoring Stations (AQMS) during June 2019 which represents the dry season. Each AQMS produces 150 PSI data in June with each parameter having 30 data. Results show that the critical pollutant for all AQMS locations in DKI Jakarta is O3. A high level of surface O3 at various stations is associated with public health risks, including respiratory tract irritation, difficulty breathing during indoor activities, and permanent lung damage from repeated exposure.

Keywords: Air Pollution Standard Index, PSI, Jakarta, Ozone.

1 Introduction

In 2019, the air quality in Jakarta became the talk of the Indonesian people. This is because the air quality in Jakarta is said to be the worst in the world by a digital platform called AirVisual which focuses on air quality. Based on Government Regulation Number 22 of 2021 concerning Control of Air Pollution (PP No. 22 of 2021), air pollution is the entry or inclusion of substances, energy, and/or other components into ambient air by human activities so that it exceeds the ambient air quality standard that has been set. In addition, the same regulation explains that the ambient air quality standard is an air pollutant value that is tolerated in the ambient air [1]. Air quality can be influenced by human activities and natural activities. Human activities include

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the transportation sector, industrial sector, and physical development. Natural activities include volcanic eruptions and forest fires. In the case of Jakarta's air quality, the increase and decrease in human activity affect improving or decreasing air quality [2].

This study uses data on the concentration parameters of particulate matter 10 µm (PM10), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and nitrogen dioxide (NO2) based on the results of measurements by the Regional Environmental Laboratory (LLHD) DKI Jakarta Province in five locations of Air Quality Monitoring Stations (AQMS) in June 2019. According to the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), in 2019 the dry season starts from April to September and the rainy season starts from October to March, therefore June includes the dry season. This is supported by BMKG data that in June 2019 the rainfall in DKI Jakarta was 20-50 mm and included in the low rainfall category.

During the dry season, pollutants can increase due to low rainfall intensity and increased sunlight intensity. During the rainy season, rainwater can minimize particulates in the air because particulates can mix with rainwater that falls to the earth. Meanwhile, during the dry season, there is an increase in the intensity of sunlight which has an impact on increasing the photochemical reaction between nitrogen dioxide and sunlight to produce nitrogen monoxide and free oxygen atoms. Free oxygen atoms can then bond with oxygen to form ozone. Increasing the concentration of pollutants can affect the decrease in the air quality of an area. Poor air quality has an impact on public health. The purpose of this study was to describe the impact of air quality on health based on the value of the Air Pollution Standard Index (PSI) in a dry season period in DKI Jakarta Province.

2 Research Methodology

2.1 Air Quality Measurement

Air quality measurement uses secondary data which is done automatically and semi- real-time digitally. Measurements are carried out continuously. The measured data is received by the UPT Laboratory server every thirty minutes from each Air Quality Monitoring Station (AQMS). The data used to analyze the air quality pattern in DKI Jakarta in this study is data for June 2019. The data is presented in µg/m3 units. The method of measurement for each parameter can be seen in Table 1.

Table 1. Air Quality Measurement Method

No.	Parameter	Method	Tool Code
1	O_3	Non Dispersive Ultraviolet Absorption	Horiba APOA-370
2	CO	Non-Dispersive Infrared	Horiba APMA-370
3	SO_2	Ultraviolet Fluorescent	Horiba APSA-370
4	NO_2	Chemiluminesce	Horiba APNA-370
5	PM_{10}	Beta Ray Absorption	Verewa 701-20

This study focuses on the parameters O3, CO, SO2, NO2, and PM10 because based on the Decree of the State Minister of the Environment Number: Kep-45/MENLH/10/1997 concerning the Air Pollutant Standard Index, only these five parameters are the index parameters. The Air Pollutant Standard Index calculation is regulated in the Decree of the Head of the Environmental Impact Management Agency (BAPEDAL) No. 107 of 1997 concerning Technical Guidelines for Calculation, Reporting, and Information on the Air Pollutant Standard Index.

This study includes air quality data from the Regional Environmental Laboratory (LLHD) of DKI Jakarta Province at five Air Quality Monitoring Station (AQMS) locations in June 2019. The climate of the city of Jakarta is generally influenced by two seasons, that is the dry season (May to September) and the dry season (May to September). The rainy season (November to March). In the dry season, the southeast monsoon (SE) dominates and brings cold and dry air and little rainfall, while in the rainy season the northwest wind (NW) brings warm and wet air, resulting in high evaporation over the Java Sea (including Jakarta). as a source of precipitation [5]. In addition, based on BMKG dissemination, in 2019 the dry season starts from April to September and the rainy season starts from October to March so June is included in the dry season. This is supported by BMKG data which shows that in June 2019 the rainfall in DKI Jakarta was 20-50 mm and included in the low category.

2.2 Measurement Location

The DKI Jakarta Government monitors air quality in its territory using AQMS located in every administrative city in DKI Jakarta Province. Table 2 describes the location of each operating AQMS. The AQMS is operated by the Regional Environmental Laboratory Technical Implementation Unit (UPT), which is under the direction of the DKI Jakarta Provincial Environmental Service (DLH).

Table 2. Locations of Air Quality Monitoring Stations in DKI Jakarta

No.	Station Name	Station Location	Allotment
1	AQMS DKI 1	HI Roundabout, Central Jakarta	Traffic Center
2	AQMS DKI 2	Kelapa Gading, North Jakarta	Residential
3	AQMS DKI 3	Jagakarsa, South Jakarta	Residential
4	AQMS DKI 4	Lubang Buaya, East Jakarta	Residential
5	AQMS DKI 5	Kebon Jeruk, West Jakarta	Residential

2.3 Measurement Location

There were changes to the regulations that were in effect at the time this research was conducted and when the research was published. In 2021, the National Ambient Air Quality Standard (NAAQS) is changed based on Attachment VII of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (PPLH). In addition, the WHO Quality Standards have also changed based on the 2021 WHO Air Quality Guidelines (AQG). In general, the two references state that the ambient air quality standard values have been tightened for several pollutants. For instance, the WHO Quality Standard for PM2.5 (24-hour average), whi tightened from 10 μg/m3 based on the 2005 AQG to 5 μg/m3 based on the 2021 AQG. Meanwhile, the NAAQS for PM2.5 (24-hour average) tightened from 65 μg/m3 based on PP No. 41/1999 to 55 μg/m3 based on PP No.

22/2021. In addition, KEPBAPEDAL No. 107 of 1997 concerning Technical Guidelines for Calculation, Reporting, and Information on the Air Pollutant Standard Index has also been replaced by the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 14 of 2020 concerning the Air Pollutant Standard Index (ISPU). Above changes are not used in this study, yet this study used quality standards and calculation methods which are still valid during the data collection period, specifically Government Regulation No. 41 of 1999 concerning Air Pollution Control; WHO Air Quality Guidelines 2005; and Decree of the Head of the Environmental Impact Management Agency (BAPEDAL) No. 107 of 1997 concerning Technical Guidelines for Calculation and Reporting and Information on Air Pollution Standards Index.

The calculation to find the 24-hour average concentration for PM 10 uses Formula 2.1 and the 1-hour average concentration for SO2, CO, O3, and NO2 uses Formula 2.2.

$$24 - hour\ average = \frac{\sum 30\text{−min}\ concentration\ data\ in\ 24\ hours}{Number\ of\ data} \tag{2.1}$$

$$1 - hour\ average = \frac{\sum 30\text{−min}\ concentration\ data\ in\ an\ hour}{Number\ of\ data} \tag{2.2}$$

Calculation of PSI followed equation 2.3 based on the Decree of the Head of the Environmental Impact Management Agency (BAPEDAL) No. 107 of 1997 concerning Technical Guidelines for Calculation, Reporting and Information on Air Pollution Standards Index.

$$I = \frac{I_a - I_b}{X_a - X_b}(X_x - X_b) + I_b \tag{2.3}$$

3 Results

3.1 National Ambient Air Quality Standard (NAAQS) Compliance

Based on Table 3, all AQMS in DKI Jakarta has met the NAAQS for the PM10 parameter. The EPA quality standard has the same value as the Indonesian quality standard. However, when compared with the quality standard set by WHO, which is 50 µg/m3 for a measurement time of 24 hours, all the maximum values in Table 3 for all AQMS have exceeded the quality standard. PM 10 itself has an impact on human health, including heart rate disturbances, irritation of the respiratory tract, and worsening asthma [3].

Table 3: Comparison of PM_{10} Concentration Data with 24-Hour Standard = 150 $\mu g/m^3$

Station	Compliance Status	The amount of data	Average	Standard Deviation	Minimum	Maximum
DKI 1	Yes	30	59.92	15.57	31.61	92.29
DKI 2	Yes	30	81.80	22.07	47,48	128.27
DKI 3	Yes	30	75.42	18.66	40,20	109.58
DKI 4	Yes	30	79.63	21.17	47.38	119.13
DKI 5	Yes	30	75.78	3.53	37.40	108.33

Table 4 shows that most of the 1-hour SO2 measurement data still meet the NAAQS. However, there are some missing data (N/A). If the concentration of SO2 is compared with the US EPA NAAQS of 196 µg/m3(75 ppb), then only DKI 2 station exceeds this quality standard because the maximum value reaches 212.62 µg/m3. The concentration of SO2 cannot be compared with the WHO Air Quality Guidelines (AQG) because the WHO measurement time is 8 hours while the Indonesian quality standard is only 1 hour. The health impact of exceeding the SO2 quality standard is increasing asthma symptoms, worsening bronchitis, and worsening emphysema [7].

Table 4: Comparison of SO_2 Concentration Data with 1-Hour Standard = 900 µg/m^3

Station	Compliance Status	The amount of data	Average	Standard Deviation	Minimum	Maximum
DKI 1	Yes	710	14.12	7.39	2.17	43.75
	N/A	10	-	-	-	-
DKI 2	Yes	707	20.36	16.25	10,15	212.62
	N/A	13	-	-	-	-
DKI 3	Yes	684	18.61	3.13	8.88	32.42
	N/A	36	-	-	-	-
DKI 4	Yes	714	40,30	4.51	34.23	65,80
	N/A	6	-	-	-	-
DKI 5	Yes	711	30.31	8.34	18.63	71.89
	N/A	9	-	-	-	-

Based on Table 5, all available data are below the applicable quality standards in Indonesia. When compared with the EPA, all available data is still below the quality standard because. This is because the quality standard set by the EPA is looser than in Indonesia, which is 40,000 µg/m3. The health impact arising from exceeding the CO quality standard is the reduced supply of oxygen in the human body [2].

Table 5: Comparison of CO Concentration Data with 1-Hour Standard = 30.000 µg/m^3

Station	Compliance Status	The amount of data	Average	Standard Deviation	Minimum	Maximum
DKI 1	Yes	709	1479.51	684.40	342.51	4421.80
	N/A	11	-	-	-	-
DKI 2	Yes	708	759.14	479.07	107.96	2639,40
	N/A	12	-	-	-	-
DKI 3	Yes	689	1191.19	629,20	382.62	5076.90
	N/A	31	-	-	-	-
DKI 4	Yes	715	1095.46	665.29	152.25	5522.75
	N/A	5	-	-	-	-
DKI 5	Yes	709	1358,22	508.99	653.83	3332.30
	N/A	11	-	-	-	-

Based on Table 6, O3 concentrations exceed the Indonesian NAAQS, but the majority of the data are below the applicable NAAQS. The O3 concentration cannot be compared with the EPA and WHO because the measurement time used is different, that is 8 hours. The health impacts of exceeding the O3 quality standard include respiratory tract irritation, difficulty breathing during indoor activities, and permanent lung damage from repeated exposure [2].

Table 6: Comparison of O_3 Concentration Data with 1-Hour Standard = 235 µg/m^3

Station	Compliance Status	The amount of data	Average	Standard Deviation	Minimum	Maximum
DKI 1	Yes	705	57,00	42.45	7.95	204.99
	Not	2	252.59	4.75	249.23	255.95
	N/A	13	-	-	-	-
DKI 2	Yes	694	86.64	48.46	8.92	234.68
	Not	6	257.05	20.93	239.02	295.81
	N/A	20	-	-	-	-
DKI 3	Yes	681	98.02	53.99	16.02	234.16
	Not	12	258.65	21.02	236.14	304.30
	N/A	27	-	-	-	-
DKI 4	Yes	702	73.96	57.35	0.58	227.93
	Not	8	264.48	18,90	239.32	289.67
	N/A	10	-	-	-	-
DKI 5	Yes	701	77.00	58,18	2.74	233.11
	Not	10	259.30	21.24	236.46	301.29
	N/A	9	-	-	-	-

Based on Table 7, most measurements do not exceed the NAAQS in Indonesia and some data are not available. When compared with WHO, which is 200 µg/m3, and EPA which is 188 µg/m3 also there is no data that exceeds the quality standard. The health impacts of exceeding the NO2 quality standard include respiratory tract inflammation and increased asthma symptoms [2].

Table 7: Comparison of NO_2 Concentration Data with 1-Hour Standard = 400 µg/m^3

Station	Compliance Status	The amount of data	Average	Standard Deviation	Minimum	Maximum
DKI 1	Yes	710	47.22	18,19	12.46	133.37
	N/A	10	-	-	-	-
DKI 2	Yes	706	20.78	15.67	0.78	68.32
	N/A	14	-	-	-	-
DKI 3	Yes	570	28.82	15.91	2.43	90.58
	N/A	150	-	-	-	-
DKI 4	Yes	712	23.98	14.56	2.04	93.74
	N/A	8	-	-	-	-
DKI 5	Yes	711	24.02	13.24	0.39	67.86
	N/A	9	-	-	-	-

3.2 Air Pollutant Standard Index

In the Decree of the State Minister of the Environment Number 45 of 1997, it is known that PSI is used as information material for the public about ambient air quality at a certain location and time. PSI is a number that does not have units that describe the condition of ambient air quality at a certain location and time based on the impact on health, aesthetic value, and other living things [4]. The PSI range can be seen in Table 8.

Table 8: Categories for the Pollutant Standard Index

No.	Category	Range
1	Good	0-50
2	Moderate	51-100
3	Unhealthy	101-199
4	Very Unhealthy	200-299
5	Dangerous	300-over

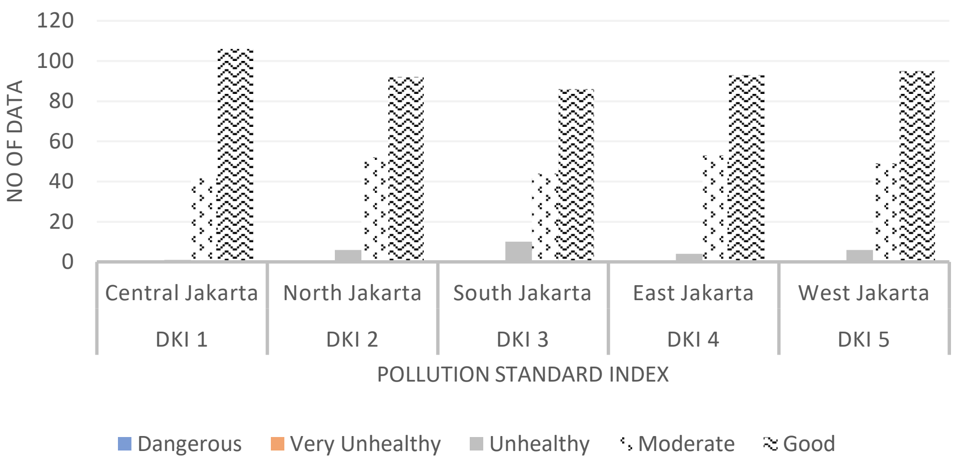


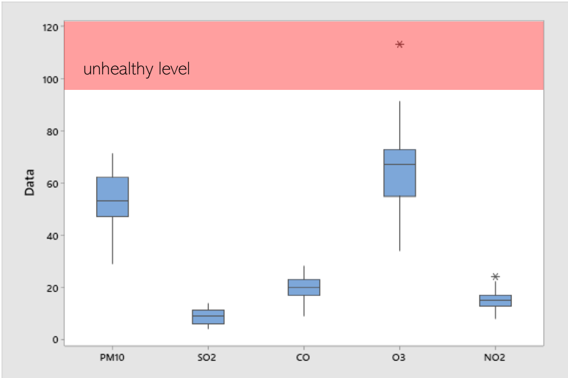
Fig. 1. Comparison of Air Pollutant Standard Index Values during June 2019

Each AQMS received 150 PSI data in June with each parameter having 30 data. Based on Figure 1, for AQMS DKI 1 there was 1 data in the unhealthy category, 42 data included in the moderate category, 106 data in the good category, and there was one day for which there was no PSI data. In AQMS DKI 2 there are 6 data in the unhealthy category, 52 data including the moderate category, and 92 data including the good category. AQMS DKI 3 has 10 data in the unhealthy category, 44 data in the moderate category, 86 data in the good category, and 10 data in the missing category. In AQMS DKI 4 there are 4 data in the unhealthy category, 53 data in the medium category, and 93 data in the good category. AQMS DKI 5 has 6 data in the unhealthy category, 49 data in the moderate category, and 95 data in the good category.

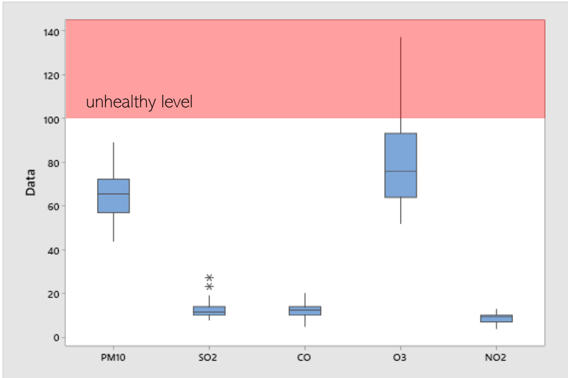
Although the PSI category that most often appears is the good and moderate category, several days reached the unhealthy category. Of all locations, South Jakarta (AQMS DKI-3) is the area with the worst air quality because there are 10 days out of 30 days in the unhealthy category.

These unhealthy categories can have an impact on living things. Based on the Decree of the State Minister of the Environment Number 45 of 1997 concerning the Air Pollutant Standard Index (PSI), in the unhealthy category, the air quality level is detrimental to humans or sensitive animal groups or can cause damage to plants or aesthetic value.

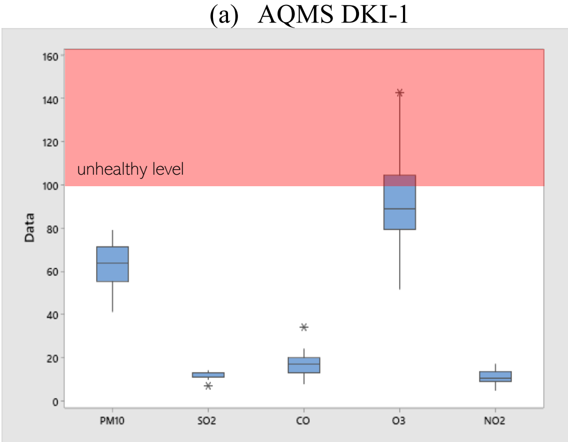
Figure 2 describes a boxplot distribution of ISPU values during June 2019. A boxplot describes the distribution of the data statistically where the mean, quartile, minimum, and maximum values of a dataset are presented using a box and a whisker so that it is helpful to compare visually. The mean value of the data is the centerline of the box, while its whiskers are the maximum and minimum values. Based on a comparison between parameters, O3 and PM10 have higher PSI values for all AQMS locations. Historically, parameters O3 and PM10 are two pollutants that cause PSI to be above unhealthy levels above 100 [3]. The graphs also showed that the lower whisker or minimum value of O3 does not intersect with the upper whisker or maximum value of several parameters such as NO2, so it can be concluded that the value is significantly different.



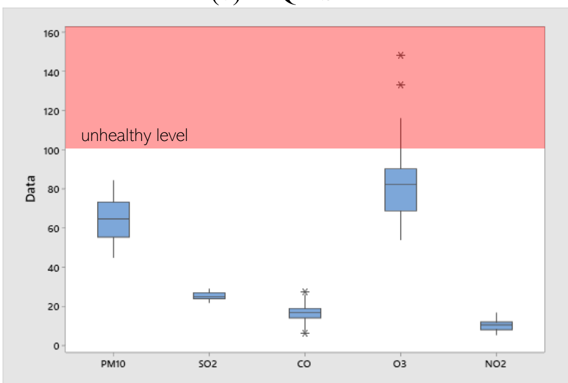
(a) AQMS DKI-1



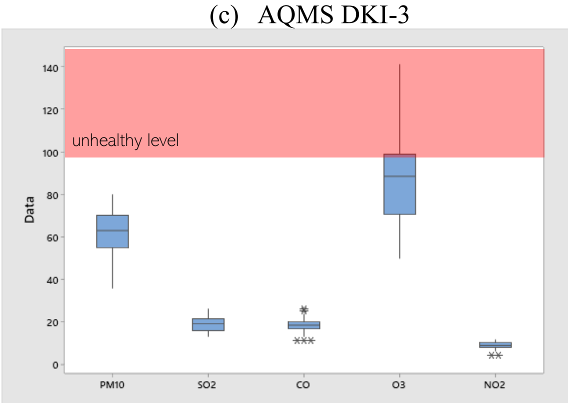
(b) AQMS DKI-2



(c) AQMS DKI-3



(d) AQMS DKI-4



(e) AQMS DKI-2

Fig. 2. Boxplot of PSI Value and Critical Pollutant

A critical pollutant is a parameter that has the highest PSI value among the other PSI parameters, or in the other words, higher pollution levels relative to each threshold value. There is one critical pollutant parameter every day for each AQMS. Based on Figure 2, it can be concluded that the critical pollutant for all locations in DKI Jakarta is O3, which is seen to have a significantly higher value than the other parameters. O3 is also the only parameter whose PSI value exceeded 100 for all locations, which is categorized as an unhealthy condition (Table 3). A high level of surface O3 at various stations indicates public health risks, including respiratory tract irritation, difficulty breathing during indoor activities, and permanent lung damage from repeated exposure. Based on the government regulations, there are recommendations for activities during the unhealthy air quality period: 1) for sensitive groups: outdoor activities are allowed, but take more breaks, do light activities, watch for symptoms such as coughing or shortness of breath; 2) for people with asthma: they should follow health instructions for asthma and stock up on asthma medications; 3) for people with heart disease, symptoms such as palpitations/rapid heartbeat, shortness of breath, or unusual tiredness may indicate a serious problem; 4) for everyone else, it is recommended to reduce prolonged physical activity outdoors. Citizens of Jakarta with frequent exposure to air pollution should take more care and consideration when doing activities outdoor, especially in conducting heavier physical activities for people with health risks.

4 Conclusions

Based on the DKI Jakarta PSI value in the 2019 Dry Season, it was found that the air pollution categories generally belonged to the good and moderate categories, with some days reaching the unhealthy category. Based on data from all stations, South Jakarta is the area with the worst air quality because there are 10 days out of 30 days in the unhealthy category. These unhealthy categories can have an impact on living things. In the unhealthy category, the level of air quality poses a negative health risk to humans or sensitive animal groups can cause damage to plants or aesthetic value. Based on the boxplot of the distribution of PSI values, it can be concluded that in June 2019 for all AQMS the values of O3 and PM10 had significantly higher values than other parameters. The PSI parameter in DKI Jakarta which is the critical pollutant parameter for all locations is O3.

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