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Multivariate Analysis ANOVA Based Distribution of Nitrogen Dioxide in Lampung Barat And Way Kanan Regencies

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Abstract

The rise of construction projects and population growth, followed by the expansion of industry and any other sectors such as housing estate, offices, and transportation, can lead to not only economic growth but also negative impacts such as air pollution, including nitrogen dioxide (NO_2) pollutants. According to KEP-45/MENLH/10/1997, air pollution can be determined by The Pollutant Standards Index (PSI). The statistical analysis result employing the multivariate ANOVA test with the Anderson-Darling method showed the impact of NO_2 concentrations on four location points over two years. Meanwhile, the data result of PSI revealed a high level of ambient air NO_2 in Lampung Barat Regency, particularly at the monitoring point of offices. On the other hand, in Way Kanan Regency, the level of ambient air NO_2 tends to be safe and secure at the monitoring point of industry and transportation. The factor of sampling location and technique (stage 1: dry season, stage 2: rainy season) did not give a significant effect on the NO_2 level due to a p-value ≥ 0,05. However, the sampling point (of monitoring) influenced the NO_2 level for p-value ≤ 0,05 in Lampung Barat and Way Kanan Regency in 2019-2020 which was still claimed as safe and secure based on PP No. 41 in the Year 1999, which sets the required limit at 100 g/m^3.

Keywords: *Air pollution; Lampung Barat; NO_2; PSI; Way Kanan*

Introduction

Air pollution turns into a problem that occurs every year in many regions. Various solid, liquid, and gas particles, including those from factories and vehicle exhausts, can pollute the air. Unpolluted air commonly contains 20% oxygen, 78% nitrogen, 0.93% argon, 0.03% CO_2, and other gases, such as neon (Ne), helium (He), methane (CH_4), and hydrogen (H_2) in gaseous form. Meanwhile, the air is polluted when it is contaminated with additional gas causing turmoil and changes in air composition. Therefore, it requires particular efforts to monitor air pollution, one of which is the use of the NO_2 (Nitrogen dioxide) parameter which has the highest level of toxicity (Fekih, *et al.,* 2020).

Nitrogen dioxide (NO_2) is an air pollutant that can come from any place, particularly from the transportation, industrial, residential, and office sectors relating to human activities. If the concentration of NO_2 in the air exceeds The Pollutant Standards Index (PSI), it can emerge negative effects including the phenomena of acid rain and health issues such as cough, low visibility, and various respiratory problems (Show and Chang, 2016).

Furthermore, air pollution can cause a decrease in air quality. When it continues to happen, the problems of health and, even, climate change can appear. The rise of construction projects and population growth followed by the growth in other sectors such as industry, offices, and transportation will have a positive impact on the current economy. On the contrary, it also has a negative impact on the rise of air pollution (Gualtieri et *al.,* 2017).

Data from the Central Bureau of Statistics in Lampung Province (2021) reveals that Way Kanan Regency with its capital city, Blambangan Umpu, possesses an area of around 3,657.49 km^2 with an altitude of 71 meters above sea level, consisting of 14 (fourteen) sub-districts. In addition, in 2020, the population of this regency accomplished 473.580 residents. Meanwhile, the Lampung Barat Regency, with its capital city, Liwa, owns an area of 2,118.76 km^2 with an altitude of 908 meters above sea level, consisting of 15 (fifteen) sub-districts, with 302.140 people in 2020. Air quality can decrease and vary due to human activities, which may refer to physical and chemical changes (Darmawan, 2018).

The Ministry of Environment and Forestry (2020) defines that the Pollutant Standards Index (PSI) as a number without units representing the condition of ambient air quality in certain areas based on its impact on human health, aesthetic values, and other living creatures. This information can become an early warning system for the surrounding community, particularly those living in areas prone to forest and land fires. The purpose of developing PSI is to make it easier for the general public to access information about ambient air quality at certain times and locations. Additionally, for the central and regional governments, it is also used as material for considering the efforts to reduce air pollution.

According to the Decree of The Minister of Environment and Forestry, KEP 45/MENLH/10/1997 and KEP-107/KABAPEDAL/11/1997 concerning The Pollutant Standards Index (PSI), the standard air quality index that is officially applied in Indonesia is called *ISPU (Indeks Standard Pencemar Udara)*. The number of motor vehicles on the road can increase the amount of nitrogen oxide gas. Further, the sunrise produces ultraviolet light that can improve the gas change; from NO to NO_2. According to PSI, the threshold limit for NO_2 in the air is less than 100. This research was conducted to determine air quality from one of the PSI parameters, namely NO_2, Lampung Barat and Way Kanan Regencies by comparing air quality at four location points in industrial, office, residential, and transportation (traffic) areas. In this study, a statistical ANOVA test was implemented to identify the effect of NO_2 concentration for four locations. The determination of these four location points is based on relevant factors such as dominant wind direction, traffic movement, and other potential sources of pollution over two years, following PP No. 41 Year 1999.

Currently, there is no specific research on air quality in Lampung Barat and Way Kanan Regencies, while the related studies are essential to conducting monitoring and comprehending the air quality in those areas. This recent study presents the relevant data collected to withdraw more accurate conclusions on air quality. This will be an important basis for further research on air quality in the area.

Methods

Tools and Materials

The materials used in this study were sulfanilic acid, glacial acetic acid solution, mineral-free water, sodium nitrite, N-(1-naphthyl)-ethylenediamine dihydrochloride mother liquor, acetone, Griess-Saltzman absorbent solution, and nitrite mother liquor (NO_2). While the tools used are NO_2 test sampling equipment, volumetric flask, microburette, measuring cup, goblet, UV-Vis spectrophotometer, analytical balance, oven, dark bottle, barometer, thermometer, desiccator, and watch glass.

Work Procedures

First is arranging the test sampling equipment, then placing it in the position and measurement location according to the method of determining the location of ambient air quality monitoring test sampling based on SNI 19-7119.6. Put 10 mL of Griess-Saltzman sorbent solution into the sorbent bottle, then set the sorbent bottle to be protected from rain and direct sunlight. Turn on the air suction pump and set the flow rate to 0.4 L/min. After stabilizing, record the initial flow rate and monitor the air flow rate at least once every 15 minutes. Take the test sample for 1 hour and record the temperature and air pressure. Furthermore, sample testing was carried out with a UV-Vis spectrophotometer (SNI 7119-2: 2017).

The Pollutant Standard Index (PSI) value of NO_2 in 2019-2020 at four monitoring points (industry, offices, settlements, and transportation) in two regencies in Lampung Province was obtained from the Regional Environmental Supervisory Agency (BPLHD) of Lampung Province. Monitoring of PSI values is carried out in two stages in one year by BPLHD Lampung Province. The two stages are carried out in the rainy and dry season months. The complete location and coordinates of the four monitoring points in the Lampung Barat and Way Kanan Regencies can be seen in Tables 1 and 2. The PSI values obtained are then used to categorize air quality conditions at the monitoring points. The qualification of air quality conditions can be seen in Table 3.

Table 1. Lampung Barat Monitoring Location Points

Code	Monitoring Point	Address	Coordinate Point	
			East longitude	South latitude
01	Transport	Terminal Pasar Liwa	S: 05° 02' 18,3"	E: 104° 05' 00,8"
02	Industry	Jl. Lintas Liwa-Krui Pekon Kubu Perahu Kec. Balik bukit	S: 05° 05' 26,3"	E: 104° 25' 48,4"
03	Settlements	Gunung Sugih Kec. Balik Bukit	S: 05° 01' 39,5"	E: 104° 06' 01,5"
04	Office	Jl. Tulip No. 2 Way Mengaku	S: 05° 01' 09,4"	E: 104° 03' 33,5"

Table 2. Way Kanan Monitoring Location Points

Code	Monitoring Point	Address	Coordinate Point	
			East longitude	South latitude
05	Transport	Jl. Lintas Sumatera Kp. Cegah, Kec. Baradatu	S: 04° 40' 44,4"	E: 104° 32' 18,2"
06	Industry	Jl. Lintas Sumatera Kp. Cegah, Kec. Baradatu	S: 04° 40' 44,3"	E: 104° 32' 17,6"
07	Settlements	Komplek Perumahan Daedang Kec. Belambangan Umpu	S: 04° 31' 41,7"	E: 104° 30' 25,7"
08	Office	Komplek Perkantoran PEMDA Km. 02 Kec. Belambangan Umpu	S: 04° 30' 34,3"	E: 104° 30' 34,3"

Table 3. Air quality categories based on PSI values based on Environmental Impact Management Agency *(Bapedal)* Head Decree No. 107 of 1997

No.	PSI Value	Category
1.	0-50	Good
2.	51-100	Medium
3.	101-199	Unhealthy
4.	200-299	Very unhealthy
5.	> 300	Dangerous

According to KEP-45/MENLH/10/1997 and KEP-107/KABAPEDAL/11/1997, the variables used to calculate PSI are 10 μm particulates (PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), oxidants such as ozone (O_3), and nitrogen dioxide (NO_2). The following formula can be used to determine the PSI Value:

$$I = \frac{(Ia-Ib)}{(Xa-Xb)}(Xx - Xb) + IbI = \frac{Ia-Ib}{Xa-Xb}(Xx - Xb) + Ib$$

Where I is measurement of PSI; Xa is maximum allowable ambient level (μg/m^3); Ia is PSI upper limit; Xb is an Ambient limit (μg/m^3); Ib is PSI lower limit; and Xx is the apparent ambient levels as measurement result (μg/m^3).

The measured concentration of air pollution parameters higher or lower than the national ambient air quality standard value is usually used to determine air quality. The upper quality limit of ambient air quality to prevent air pollution is stipulated in Government Regulation No. 41/1999 on national ambient air quality standards. Table 4 displays the National ambient air quality standards.

Table 4. National Ambient Air Quality Standard according to Government Regulation No. 41, Year 1999

Parameters	Time	Quality Standard (μg/m^3)
Particulates (PM_{10})	24 hours	150
Carbon monoxide (CO)	1 hour	30000
	24 hours	10000
Ozone (O_3)	1 hour	235
	1 year	50
Sulfur dioxide (SO_2)	24 hours	365
	1 year	80
Nitrogen dioxide (NO_2)	1 hour	0.25
	1 year	100

Furthermore, the ANOVA *(*Analysis of Variance*)* test was used in statistical analysis in this study, namely the *multivariate* correlation test. In the *multivariate* test, the factors of monitoring location point, sampling, and location were added to the resulting NO_2 levels.

Results and Discussion

The PSI values and categories for the parameter NO_2 from four monitoring points (Figure 1) in two regencies in Lampung

Province can be seen in Tables 5 and 6. In determining the category of PSI at each monitoring point, the data from Table 6 is compared with the Decree of the Head of Bapedal Number 107 Year 1997 on PSI. Based on the data in Table 7, the concentration of NO_2 at each monitoring point in Lampung Barat and Way Kanan Regency is included in the safe and harmless category. The effect on human health, aesthetic appeal, and other living things determines the value of the Pollutant Standard Index (PSI). It applies to all types of locations, describing the state of ambient air quality at the sampling location (Gusti, 2019).

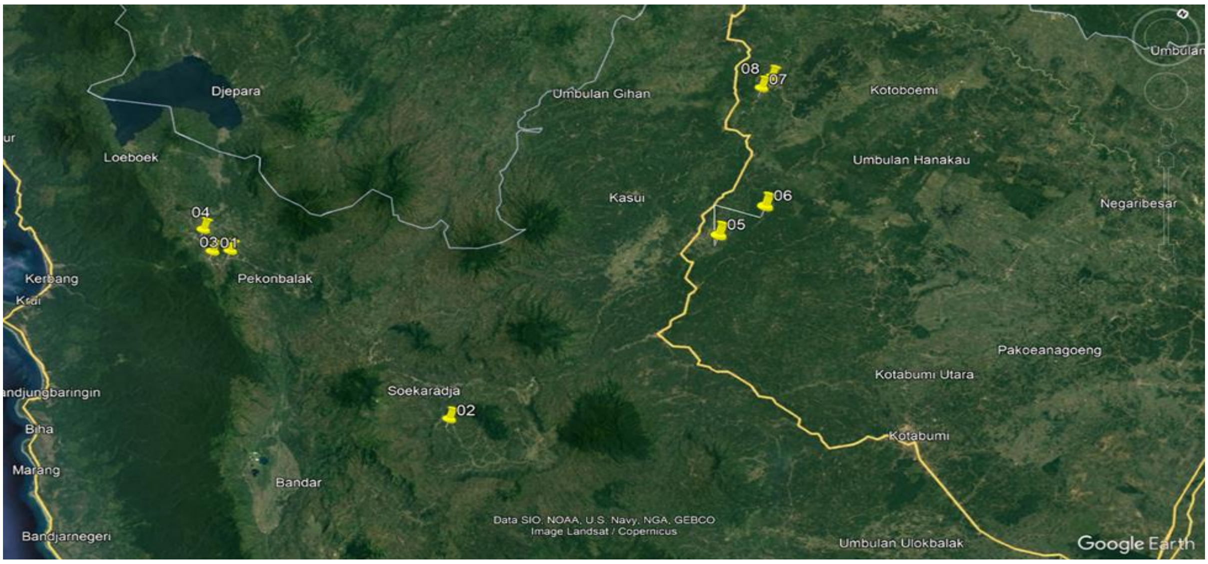

Figure 1. Monitoring Points in Lampung Barat and Way Kanan Regencies

Table 5. Calculated Data of PSI Value Parameter NO_2 ($\mu g/m^3$)

Year	District	Transport	Industry	Settlements	Office
2019	Lampung Barat	0.93	1.05	0.88	2.03
	Way Kanan	3.67	2.43	0.64	0.70
2020	Lampung Barat	0.78	0.80	0.93	1.77
	Way Kanan	3.18	3.41	0.78	1.37

Table 6. PSI Categories at Sampling Points

Year	Location	Sampling Point Category			
		1	2	3	4
2019	Lampung Barat	Good	Good	Good	Good
	Way Kanan	Good	Good	Good	Good
2020	Lampung Barat	Good	Good	Good	Good
	Way Kanan	Good	Good	Good	Good

The Ministry of Environment and Forestry (2020) states that the PSI index is in the good range (0–50 $\mu g/m^3$) and that exposure to NO_2 produces a faint odor. Based on the PSI value obtained in the study, it is still in the good category with a range below $\mu g/m^3$. The initial effect of NO_2 concentrations on human health and other living things is to cause unpleasant odors. Secondly, exposure to NO_2 produces odors with higher PSI values in the medium category (51–100 μg/m³). Thirdly, exposure to NO_2 causes the gas to start to smell unpleasant and lose its color. All of which affect how responsive the neck vessels are in asthma sufferers. an even higher range at a PSI index of 101–199 g/m3 is included in the unhealthy category. Fourthly, people with asthma and bronchitis will become more sensitive to NO_2 in the range of 200–299 μg/m³, which is classified as very unhealthy. Fifth, exposure to NO_2 is harmful to all groups of people if the PSI value is greater than 300 μg/m³ or falls into the harmful category. In addition, the average NO_2 concentration at each monitoring point in 2019 and 2020 was calculated using the NO_2 concentration data obtained. Table 8 displays the average NO_2 concentration results in both regencies in 2019-2020.

Based on Table 7, it shows that the highest average NO_2 concentration in Way Kanan in 2019 was at the transport monitoring point with an average of 20.75 μg/m³, while in Lampung Barat it was at the office monitoring point with an average of 11.45 μg/m³. The next highest average concentration of NO_2 in 2020 in Way Kanan was at industrial monitoring points with an average of 19.26 μg/m³, while in Lampung Barat it was at office monitoring points with an average of 9.98 μg/m³. Based on data from the Lampung provincial statistics agency, it is caused by the temperature in Way Kanan Regency being higher than in Lampung Barat. The results of the average concentration of NO_2 both in phase 1 (rainy season) and phase 2 (dry season) measurements at four monitoring point locations did not exceed the established quality standard of 100 μg/m³ annually which is based on Government Regulation No. 41 of 1999. According to meteorological data, surface gases and air particles warm up at high air temperatures, which causes the increase of NO_2. Thus, there is a tendency for the concentration of gases and particles, especially the concentration of NO_2, will increase as the air temperature rises. The increase in air humidity and the decrease in air temperature influence the measured amount of NO_2 concentration.

Previous research on the NO_2 parameter in three locations in Bandar Lampung City in May 2016 showed that the PSI value was in a good category and still below the limit. It indicates that the city's air pollution at that time was still under control due to interaction with the number of vehicles in the city continuing to grow (Arissa and Kiswandono, 2017). A subsequent study on air quality analysis for NO_2 in DKI Jakarta province revealed that NO_2 measurements from 2014 to 2018 showed regional zone changes rather than an increase in air quality that had high pollution levels as a result of the construction of various government buildings and sizable malls (Agista *et al.*, 2020).

If it is not well-handled immediately, high concentrations of NO_2 pollution can damage the human respiratory tract, and cause inflammation and paralysis of the respiratory system. High concentrations of NO_2 pollutants can also irritate the eyes, eye damage and redness (Suyono, 2014). When it rains, NO_2 pollution can react with rainfall to produce the chemical acid compound HNO_2 or HNO_3 if the level of NO_2 pollution in the air is high. Then acid rain occurs, which poses a serious threat to animal and plant growth (Agista *et al.,* 2020). In addition, the largest greenhouse gas contributor to global warming is NO_2, which is a by-product of fuel combustion. NO_2 which naturally contains the element nitrogen, is a secondary result of burning gasoline in vehicle engines (Darmawan, 2018).

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Table 7. Results of Average NO_2 Concentration at Each Sampling Point in Two Regencies

Year	Location	Sampling Point	Sampling Stage	NO_2 levels	Average
2019	Way Kanan	Transport	1	21.8	20.75
			2	19.7	
		Industry	1	16.3	13.75
			2	11.2	
		Settlements	1	3.6	3.6
			2	3.6	
		Office	1	3.7	3.93
			2	4.17	
	Lampung Barat	Transport	1	5.3	5.25
			2	5.2	
		Industry	1	5	5.95
			2	6.9	
		Settlements	1	5.2	4.95
			2	4.7	
		Office	1	12.4	11.45
			2	10.5	
2020	Way Kanan	Transport	1	21.15	17.975
			2	14.8	
		Industry	1	18.72	19.26
			2	19.8	
		Settlements	1	5.19	4.38
			2	3.57	
		Office	1	8.01	7.765
			2	7.52	
	Lampung Barat	Transport	1	4.37	4.4
			2	4.43	
		Industry	1	4.11	4.515
			2	4.92	
		Settlements	1	4.79	5.28
			2	5.76	
		Office	1	10.36	9.98
			2	9.6	

Based on the concentration data obtained from Lampung Barat and Way Kanan regencies, a normality test was then conducted. The results of the normality test show that the data obtained are normally distributed (Figure 2), so they can be further tested using *multivariate* ANOVA.

In statistical tests, it uses *multivariate* ANOVA to measure sampling points (monitoring) and sample taking (stage 1: dry season, stage 2: rainy season), and location on NO_2 levels.

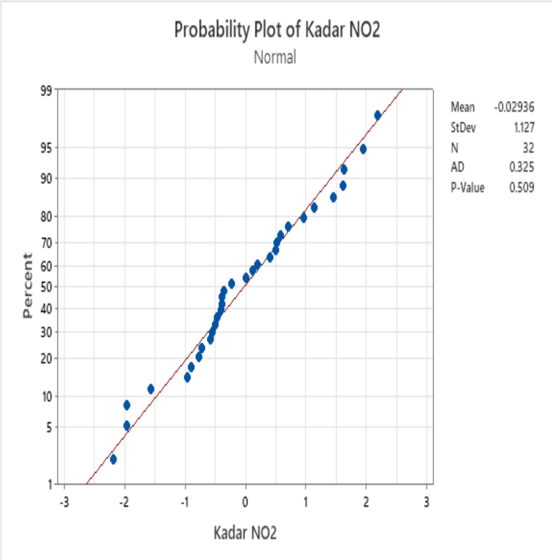

Figure 2. Probability Plot of NO_2 Ambient Air Measurement

Figure 1 shows the probability plot of the combined NO_2 ambient air measurements from both regencies (Lampung Barat and Way Kanan). It is known that with the Johson Transformation using the *Anderson-Darling* method, a *p-value* of 0.509 was obtained from four monitoring location points in 2019 and 2020, so the value of the resulting *p-value is* greater than 0.05. It indicates that the data are normally distributed.

In the ANOVA test, the location *p-value* is 0.247, the sampling point is 0.017, and the sampling has a *p-value of 0.678,* so the location and sampling factors (stage 1: dry season, stage 2: rainy season) did not have a significant effect on NO_2 level because the *p-value* ≥ 0.05. Meanwhile, the sampling point (monitoring) has a significant effect on NO_2 levels because the *p-value* ≤ 0.05 in Lampung Barat and Way Kanan Regencies in 2019-2020. Therefore, based on the ANOVA test, the NO_2 level data and the PSI values obtained can be used and valid.

Conclusion

The PSI value data obtained from the concentration of NO_2 shows that high levels of NO_2 in ambient air are found at office monitoring points in Lampung Barat Regency, while industrial and transportation monitoring points in Way Kanan Regency are still in the safe and harmless category. According to PP No. 41 of 1999, the average production of NO_2 at each monitoring location in Lampung Barat and Way Kanan Regency, Lampung Province, is still within the required limit of 100 g/m^3. Based on the results of statistical analysis using *multivariate* ANOVA with Johnson Transformation using the Anderson-Darling method, the location and sampling factors (stage 1: dry season, stage 2: rainy season) did not have a significant effect on NO_2 level because the *p-value* ≥ 0.05. While the sampling point (monitoring) has a significant effect on NO_2 levels, because of the *p-value* ≤ 0.05 in Lampung Barat and Way Kanan regencies in 2019-2020.

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