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DISTRIBUTION OF MOTOR VEHICLE VOLUMES AND AMBIENT AIR DUST LEVELS IN HOT POINTS OF YOGYAKARTA CITY, INDONESIA

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Abstract

Introduction: *Yogyakarta City, Indonesia is a center for tourism, government, education, and the economy. In line with increasing mobility and transportation, this situation has a positive impact economically, but a negative impact in terms of air pollution due to vehicle emissions. Motorized vehicles contribute to air pollution reaching 66.34% of total pollution.* $PM_{2.5}$ *is a critical parameter in the city of Yogyakarta.* ***Methods:*** *This research aims to determine the volume of motorized vehicle traffic and the distribution of dust levels in the ambient air of Yogyakarta City. Data collection used non-probability purposive sampling with the roadside method. Vehicle volume is mapped using hotspots and dust levels using interpolation.* ***Results and Discussion:*** *The average vehicle volume in the morning was 2,293.147 pcu/hour and in the afternoon it was 2,301.173 pcu/hour. The hotspot results showed that the volume of motorized vehicles in the morning category was very high at 2,921.600-5,655 pcu/hour and in the afternoon it was 3,678.800-4,558 pcu/hour. The average dust content in the morning is 0.10667 grams/m*^{3} *and in the afternoon it is 0.10240 grams/m*^{3}*. The interpolation results showed that the distribution of dust levels in the very high category in the morning was 0.17000-0.20000 grams/m*^{3} *and in the afternoon it was 0.21000-0.26000 grams/m*^{3}*.* ***Conclusion:*** *The highest average volume of vehicles occurs in the afternoon while the highest total dust content occurs in the morning.*

INTRODUCTION

The city of Yogyakarta has a limited area of 32.50 km^2 with a population in 2022 of 373,589 people. The total length of roads in 2021 did not increase, only 233.230 km, but there was an increase in motorized vehicles in Yogyakarta from 549,721 vehicles to 561,523 vehicles in 2021 of the total motorized vehicles. 84.80% were motorbikes (1). Migration of people from outside the area who work, tourists, and students are also a factor in the increase in motorized vehicles. The number of tourist visitors by type of visitor in the city of Yogyakarta in 2022 is 7,444,888 visitors. The Yogyakarta City Central Bureau of Statistics recorded the number of Yogyakarta City workers in 2022 as 248,484 workers. Apart from that, in 2022 there were 42 universities in the city of Yogyakarta under the Ministry of Education and Culture, both public and private, with a total of 61,422 students (2). The increase in motorized vehicles causes ambient air pollution by exhaust emissions, one of which is dust. Indonesia is the most polluted country in Southeast Asia with the highest $PM_{2.5}$, at 34.3 micrograms per m^3 (3). The material in $PM_{2.5}$ can cause respiratory problems such as lung cancer, premature death, acute respiratory disease, chronic lung disease and cardiovascular disease (4). Monitoring results of the Yogyakarta City Air Pollution Standard Index for 2021, $PM_{2.5}$ is a critical component in the moderate category. This category is acceptable for human health, animals, plants and outdoor activities can still be carried out, but some groups with certain conditions or sensitivities need to reduce physical activity that is too long and heavy. According to the Ministry of Environment and Forestry, moderate pollution can cause a decrease in visibility.

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The Indonesian government sets quality standards for dust content in the air. Based on Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management, the quality standard for dust in ambient air for TSP is 230 μg/m^3, PM_{10} is 75 μg/m^3 and $PM_{2.5}$ is 55 μg/m^3 for 24 hours. PM_{10} concentration measurements in 3 locations of Padang City's primary road network for 24 hours in 2018, produced dust concentrations ranging from 100.19-131.26 μg/m^3 and were below the quality standard (3). Traffic characteristics are strongly related to PM_{10} concentrations. The study of decrease in ambient air quality due to dust from motor vehicles stated that the average concentration of particulates (PM_{10}) using the quality standard method for 6 days in July 2020 was 10.34 ug/m3 and 2 days in November was 15.90 ug/m^3, still below quality standards. The same thing also happens with the Air Pollution Standard Index method with the average concentration results included in the range of 0-50, which means the ambient air has not been polluted (5). The higher the volume of motorized vehicles, the higher the concentration of PM_{10} in the ambient air. This is because vehicles with fuel are a place where hundreds of gases and aerosols are mixed which gives rise to various pollutants.

Thus, efforts are needed to measure traffic volume levels and measure dust levels in detail in the Yogyakarta City area. Sampling has not been separated by size due to limited equipment used, so the sample is in the form of total dust based on Government Regulation of the Republic of Indonesia Number 22 of 2021 especially at the border points for vehicles entering and exiting the direction of Yogyakarta City. The points are on Jl. Kyai Mojo, District. Tegalrejo, Yogyakarta City; Jl. Yogyakarta-Wates, Wirobrajan; Jl. Magelang-Yogyakarta; Jl. Rear Admiral Adisucipto 32-53, Demangan, Kec. Gondokusuman; Jl. Veterans, Muja Muju, Umbulharjo District; and Jl. Bantul Km. 1 as well as dense vehicle areas on Jl. Malioboro, Jl. Sudirman, and Jl. Mangkubumi. The aim of this research is to determine the volume of motorized vehicle traffic and the distribution of dust levels in the ambient air in the city of Yogyakarta. This research is different from other research. Data from total dust measurement and vehicle volume will be analyzed using the geographic information system method. The results of the analysis will reveal the total dust distribution which can represent other areas that were not sampled and the concentration in that area will be known for comparison with predetermined quality standards. In addition, the vehicle volume hotspot at the sampling point will also be known.

METHODS

The research uses an observational method type with a cross-sectional design. The research sample is the parameter of ambient air dust and motorized vehicles in the city of Yogyakarta which represents the existing population. The sampling technique for air dust parameters and vehicle volume uses non-probability techniques using purposive sampling. Purposive sampling is a technique for determining samples with certain considerations (6). The sample criteria are the borders for entry and exit of land vehicles to Yogyakarta City, and the roads with the densest vehicle activity based on data from the Yogyakarta City Environmental Service. Sampling considerations are based on SNI 19-7119.9-2005 concerning determining locations for sampling for roadside air quality monitoring tests.

The sampling location on the roadside is a hotspot location which is in a very sharp place for pollutant concentrations when compared to other locations. The sampling location is placed at around 100 meters or more in the city center and around 1000 meters or more in the suburbs/other areas. The sampling location is a minimum of 25 meters from the intersection to avoid the influence of other roads so that the measurement results cannot be used for comparison. Placement of the sampling tool is 1-5 meters from the roadside at a height of 1.5-3 meters from the road surface. In addition, meteorological conditions in the form of temperature, humidity, and wind speed are monitored at each sampling point to support the sampling of ambient air dust levels. Meteorological conditions can affect the presence of air pollutants in the environment both as inhibitors and triggers for the formation of pollutants (7).

Based on the sample criteria, 15 sampling points were determined. Sampling of vehicle volume as an independent variable was carried out for 15 minutes using a counter in the morning at 7 a.m. and afternoon at 3 p.m. One sampling location was carried out in one day in the morning and afternoon, so that sampling at 15 points took 15 consecutive days. Sampling at each point was carried out once without repetition with the consideration that the sampling point was the road with the densest vehicle activity according to SNI 19-7119.9-2005, so there is no difference in vehicle volume every day because Yogyakarta City is not only a student city, but also a tourist city. The results of the sampling in the form of data on the number of motorized vehicles are calculated by the planned traffic volume per hour in units of vehicles/hour with the following formula:

$$q = \frac{n}{T}$$

Description:

q = Traffic volume (vehicle/hour)

n = Number of passing vehicles

T = Observation time interval

The calculation results in vehicles/hour are then changed into units of passenger cars/hour in total. The formula used is as follows:

$$Qsmp = (emp\ LV \times LV) + (emp\ HV \times HV) + (emp\ MC \times MC)$$

Description:

Q = volume of motorized vehicles (pcu/hour)

emp LV = passenger car equivalent value for light vehicles

emp HV = car equivalent value for heavy vehicles

emp MC = passenger car equivalent value for motorcycles

LV = notation for light vehicles

HV = notation for heavy vehicles

MC = notation for motorbikes

Emp of undivided urban roads and emp of divided and one-way urban roads are based on the 1997 Indonesian Road Capacity Manual (MKJI). Dust sampling as the dependent variable was carried out at 7 a.m. and 3 p.m. Calculation of dust content used the following formula:

$$\text{Dust Level} = \frac{(B2-B1)}{V\ x\ t} \times 10^3$$

Description:

B1 = Initial filter weight (grams)

B2 = Final sample weight (grams)

V = Air flow speed (lpm)

t = Sampling time (minutes)

The calculation results are then converted to 24 hours. The controlling variables that are controlled are wind speed, air temperature, and humidity. Meanwhile, variables that are not controlled include vegetation, tall buildings, and field land.

RESULTS

Volume of Motorized Vehicles

The results of calculating vehicle volume in units of pcu/hour for each type of vehicle are added up to obtain a number that represents the total volume of vehicles at a point on the highway. The results of calculating vehicle volume at each location point in the morning and afternoon are seen in Table 1 and 2. The vehicle volume at each location point is then mapped to determine the distribution of vehicle volume as in Figure 1(a) and 1(b) and presented in graphic form as in Figure 2 to find out the highest, lowest, and average vehicle volume in the morning and afternoon.

The results of the morning motor vehicle volume hotspot analysis in Figure 1(a) show that very high motor vehicle volumes are in the range of 2,921.600-5,655 pcu/hour on roads with location codes 2 and 5 which are marked with dark red dots. Meanwhile, the volume of motorized vehicles in the very low category is in the range of 766.800-1,028.200 pcu/hour on roads with location codes 10, 11, 13, and 14 which are marked with dark green dots. Meanwhile, the afternoon motor vehicle volume hotspot analysis in Figure 1(b) shows that the very high motor vehicle volume is in the range of 3,678.800-4,560 pcu/hour found on the road with location code 6 which is marked with a dark red dot. Meanwhile, the volume of motorized vehicles in the very low category is in the range of 993.200-997.800 pcu/hour, found at 11 and 14, which are marked with dark green dots.

Based on Figure 2, the highest vehicle volume calculation results in the morning are on the road with location code 2 at 5,655.800 pcu/hour. On the other hand, the highest vehicle volume in the afternoon was on the road with location code 5 at 3,678.800 pcu/hour. There is a difference between the highest vehicle volume in the morning and afternoon of 1,977 pcu/hour where the highest vehicle volume occurs in the morning. In addition, the lowest vehicle volumes in the morning and afternoon are on roads with code 11 at 766.800 pcu/hour and 993.200 pcu/hour, respectively. The difference between the two is 226.400 pcu/hour where the highest volume occurs in the afternoon. The overall average vehicle volume in the morning was 2,293.147 pcu/hour. Meanwhile, in the afternoon it was 2,301.173 pcu/hour. The average difference in the morning and afternoon is not much different, only a difference of 8,026 pcu/hour with the highest average occurring in the afternoon.

Table 1. Morning Motorized Vehicle Volume Measurement Data

Location Code	MC	Vehicle/ hour	pcu/ hour	LV	Vehicle/ hour	pcu/ hour	HV	Vehicle/ hour	pcu/ hour	Total Vehicle/hour	Total pcu/hour
1	1,712	6,848	1,712	220	880	880	11	44	57.2	7,772	2,649.2
2	1,875	7,500	1,875	927	3,708	3,708	14	56	72.8	11,264	5,655.8
3	1,105	4,420	1,105	257	1,028	1,028	10	40	52	5,488	2,185
4	1,118	4,472	1,118	143	572	572	14	56	72.8	5,100	1,762.8
5	2,991	11,964	2,991	436	1,744	1,744	15	60	78	13,768	4,813

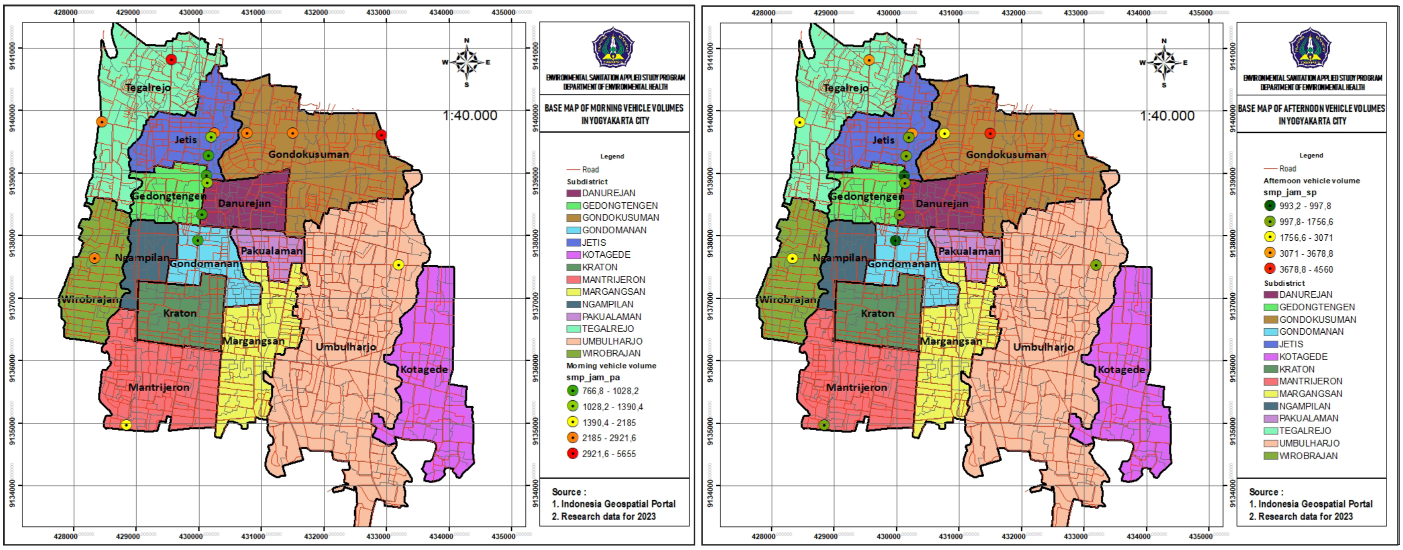
Location Code	MC	Vehicle/ hour	pcu/ hour	LV	Vehicle/ hour	pcu/ hour	HV	Vehicle/ hour	pcu/ hour	Total Vehicle/hour	Total pcu/hour
6	1,178	4,712	1,178	381	1,524	1,524	6	24	31.2	6,260	2,733.2
7	1,197	4,788	1,197	308	1,232	1,232	10	40	52	6,060	2,481
8	1,141	4,564	1,141	390	1,560	1,560	25	100	130	6,224	2,831
9	620	2,480	620	190	760	760	2	8	10.4	3,248	1,390.4
10	436	1,744	436	124	496	496	7	28	36.4	2,268	968.4
11	278	1,112	278	117	468	468	4	16	20.8	1,596	766.8
12	411	1,644	411	206	824	824	5	20	26	2,488	1,261
13	349	1,396	349	145	580	580	4	16	20.8	1,992	949.8
14	381	1,524	381	154	616	616	6	24	31.2	2,164	1,028.2
15	2,034	8,136	2,034	205	820	820	13	52	67.6	9,008	2,921.6

Information: emp MC = 0.25, emp LV = 1, emp HV = 1.3

Table 2. Data for Measuring the Volume of Motorized Vehicles in the Afternoon

Location Code	MC	Vehicle/ hour	pcu/ hour	LV	Vehicle/ hour	pcu/hour	HV	Vehicle/ hour	pcu/ hour	Total Vehicle/hour	Total pcu/hour
1	1,549	6,196	1,549	324	1,296	1,296	4	16	20.8	7,508	2,865.8
2	1,443	5,772	1,443	445	1,780	1,780	9	36	46.8	7,588	3,269.8
3	1,101	4,404	1,101	160	640	640	3	12	15.6	5,056	1,756.6
4	658	2,632	658	174	696	696	24	96	124.8	3,424	1,478.8
5	1,682	6,728	1,682	494	1,976	1,976	4	16	20.8	8,720	3,678.8
6	234	936	234	1,075	4,300	4,300	5	20	26	5,256	4,560
7	1,345	5,380	1,345	356	1,424	1,424	2	8	10.4	6,812	2,779.4
8	1,366	5,464	1,366	441	1,764	1,764	10	40	52	7,268	3,182
9	581	2,324	581	197	788	788	6	24	31.2	3,136	1,400.2
10	591	2,364	591	207	828	828	7	28	36.4	3,220	1,455.4
11	406	1,624	406	139	556	556	6	24	31.2	2,204	993.2
12	483	1,932	483	205	820	820	1	4	5.2	2,756	1,308.2
13	177	708	177	382	1,528	1,528	3	12	15.6	2,248	1,720.6
14	377	1,508	377	150	600	600	4	16	20.8	2,124	997.8
15	2,007	8028	2,007	253	1,012	1,012	10	40	52	9,080	3,071

Information: emp MC = 0.25, emp LV = 1, emp HV = 1.3



(a) **(b)**

Figure 1. Map of Vehicle Volume in the City of Yogyakarta in the Morning (a) and Afternoon (b)

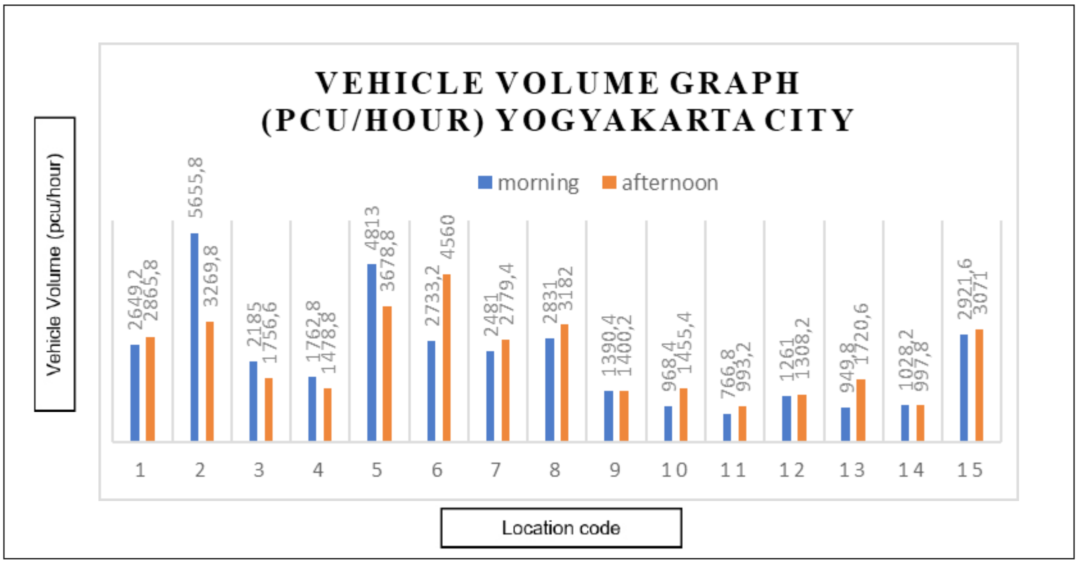
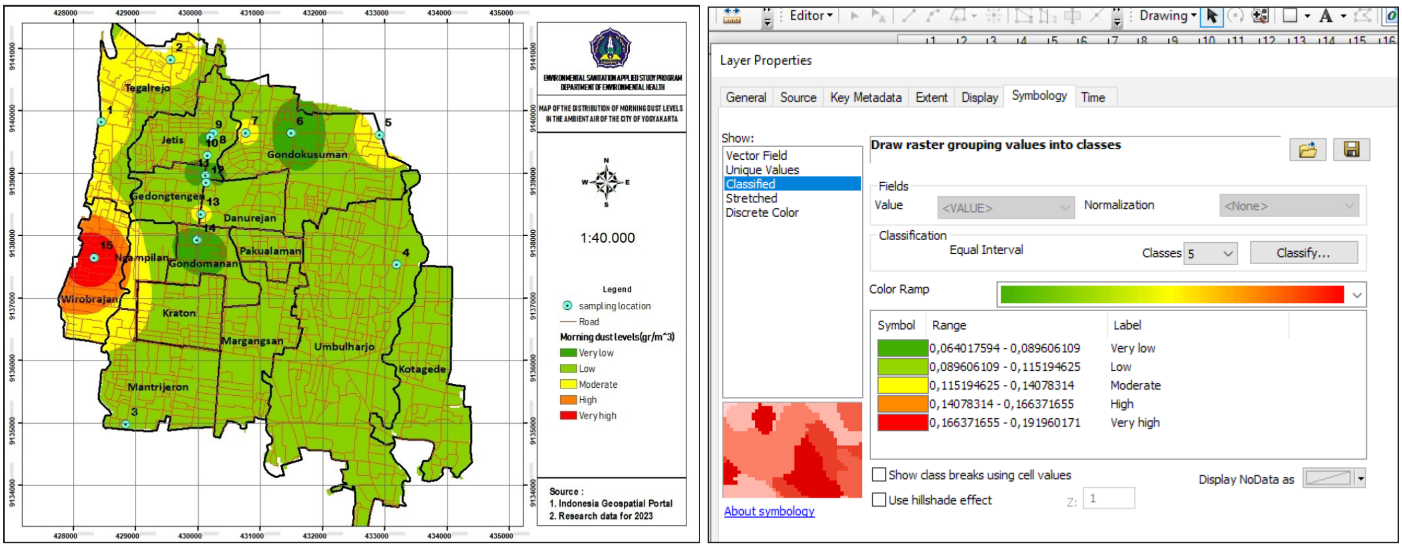
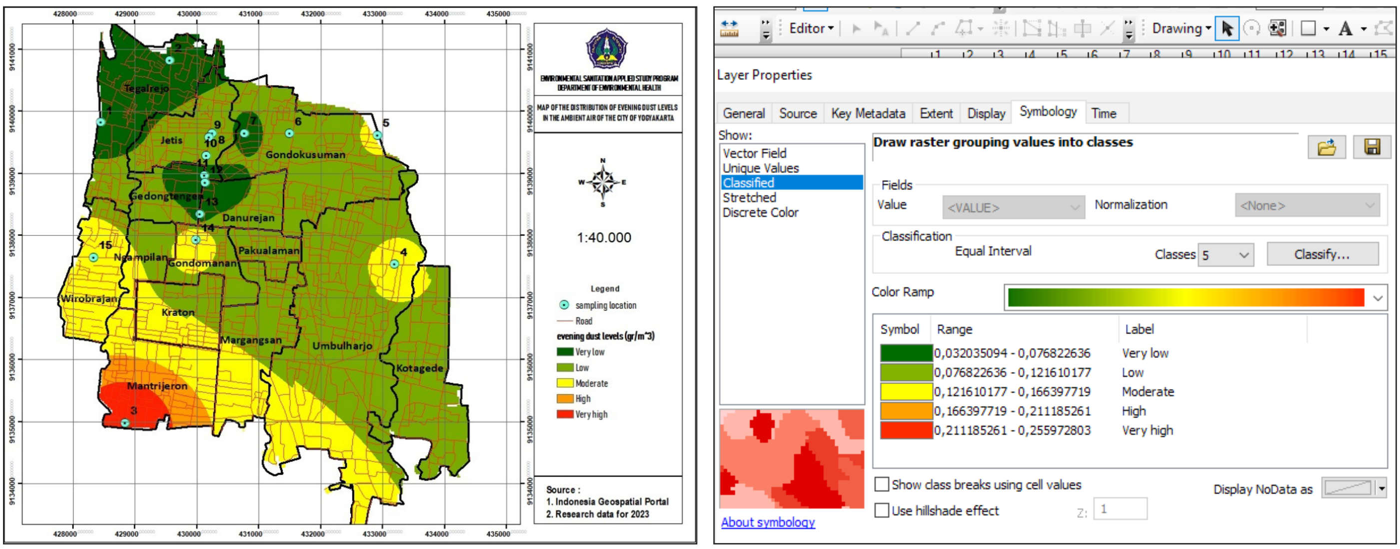


Figure 2. Graph of Vehicle Volume (pcu/hour)



(a) **(b)**

Figure 3. Map of Distribution (a) and Classification of the Distribution of Dust Content (b) of Morning Dust Levels in Yogyakarta City



(a) **(b)**

Figure 4. Map of Distribution (a) and Classification (b) of Afternoon Dust Levels in Yogyakarta City

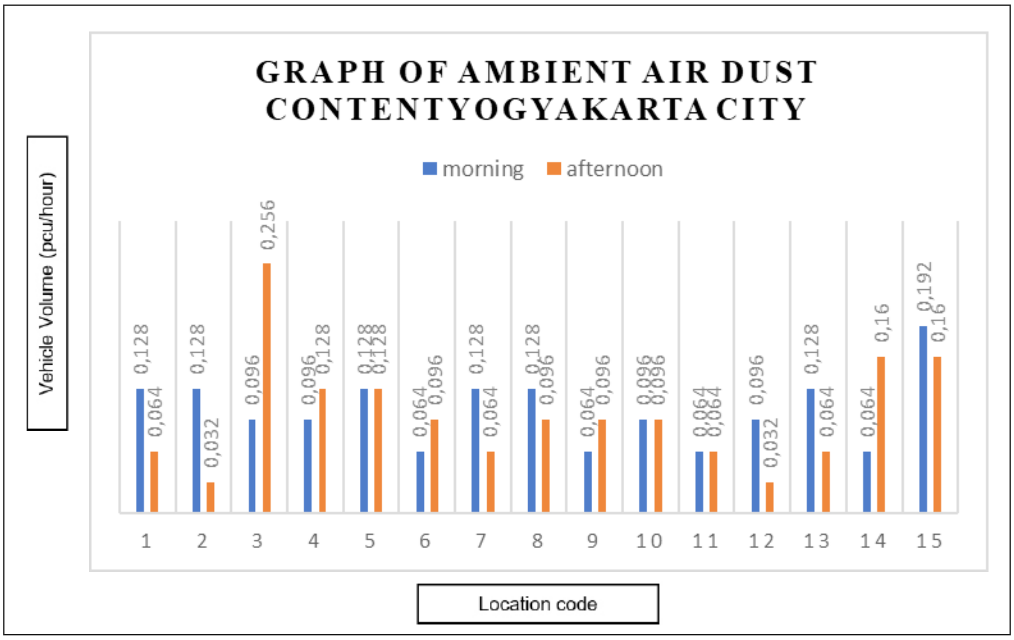
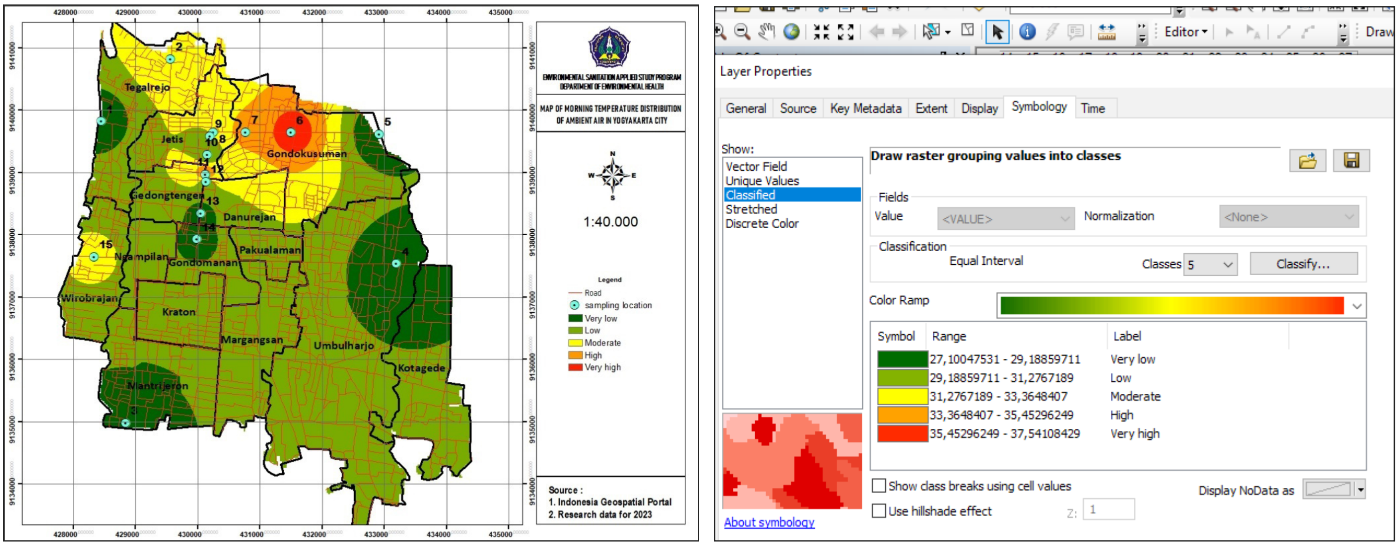
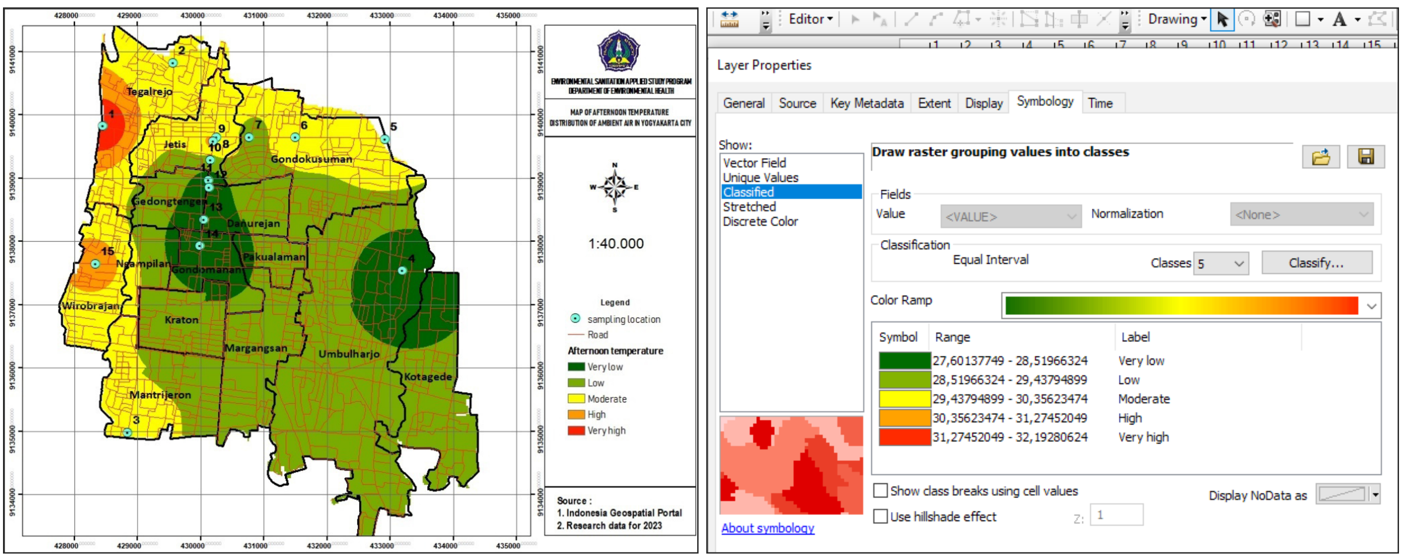


Figure 5. Graph of Ambient Air Dust Content



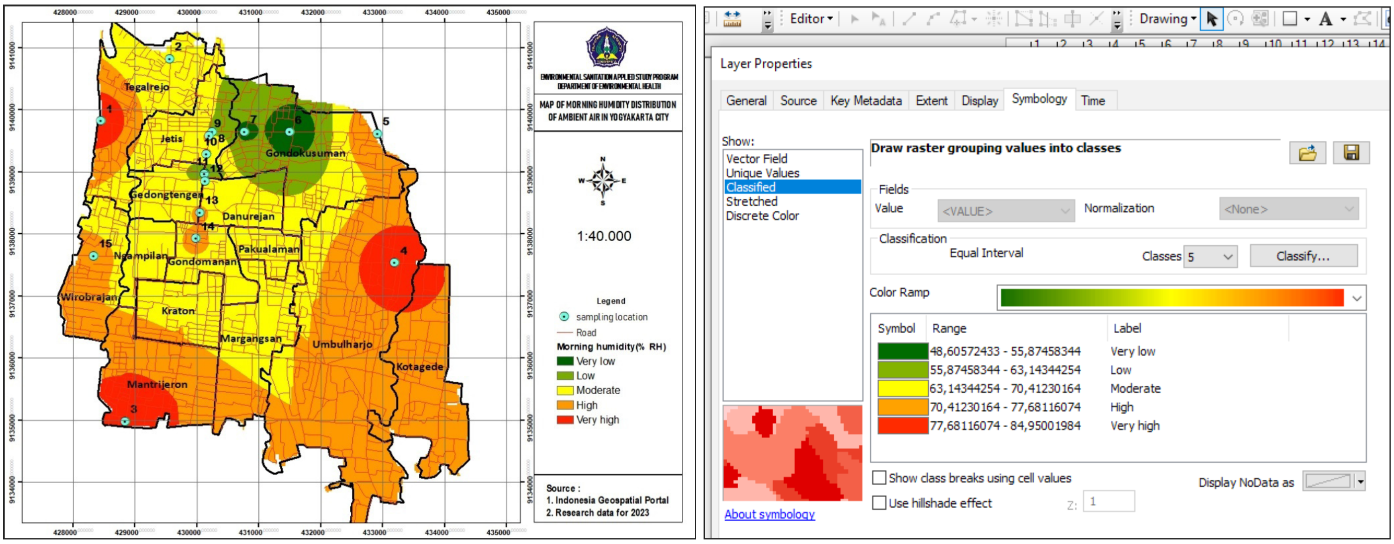
(a) (b)

Figure 6. Map of Distribution (a) and Classification (b) of Morning Temperature for Yogyakarta City



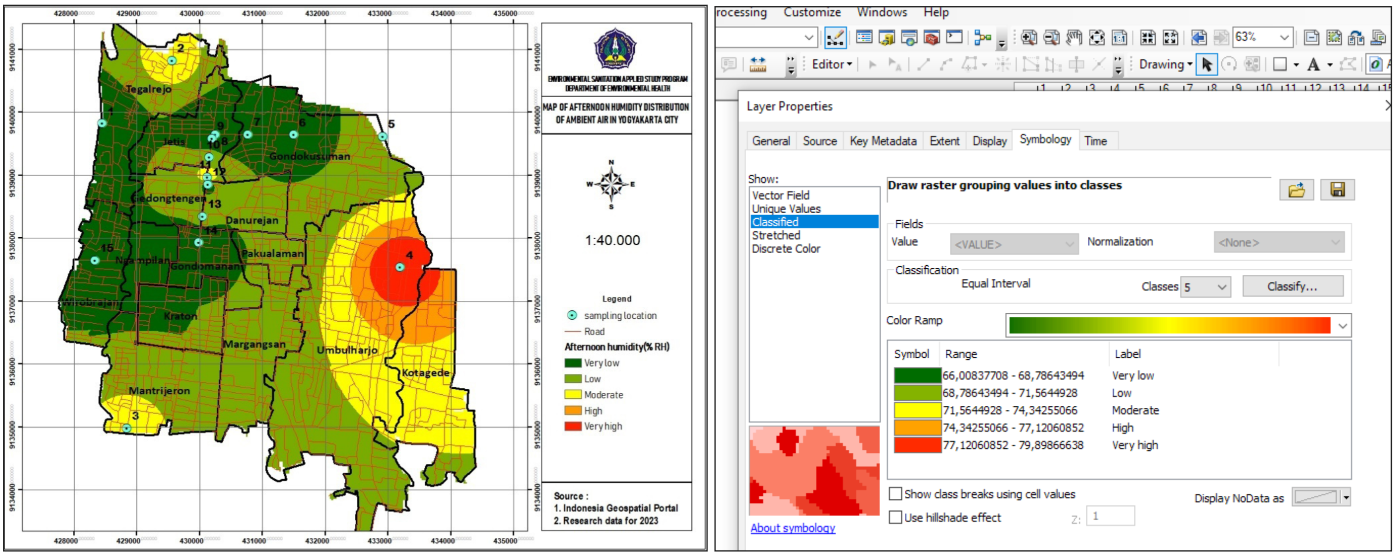
(a) (b)

Figure 7. Map of Distribution (a) and Classification (b) of Afternoon Temperature for Yogyakarta City



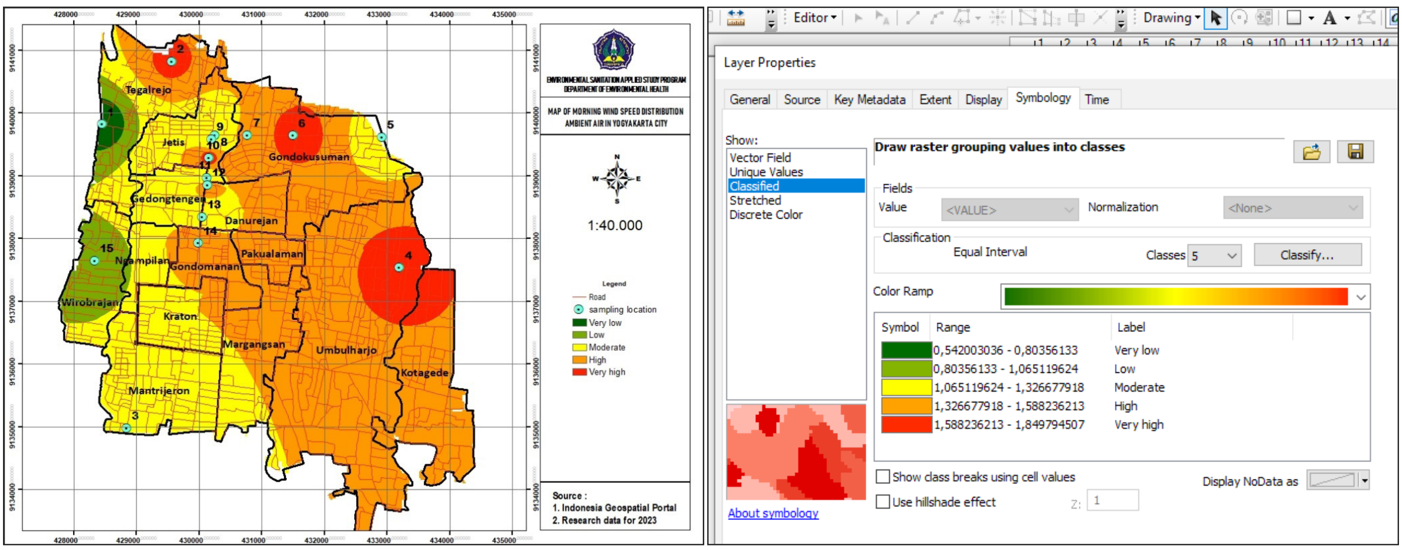
(a) (b)

Figure 8. Map of Distribution (a) and Classification (b) of the Morning Humidity in the Yogyakarta City



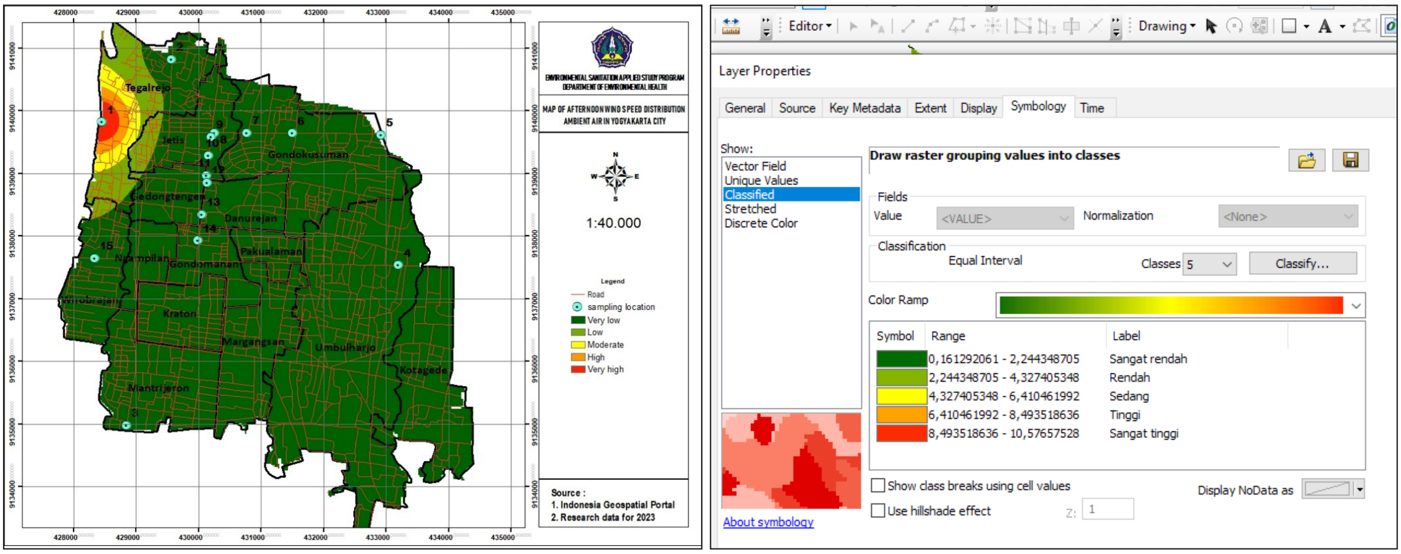
(a) (b)

Figure 9. Map of Distribution (a) and Classification (b) of humidity in the Afternoon in Yogyakarta City



(a) (b)

Figure 10. Map of Distribution (a) and Classification (b) of the Morning Wind Speed in the Yogyakarta City



(a) (b)

Figure 11. Map of Distribution (a) and Classification (b) of the Afternoon Wind Speed in Yogyakarta City

Dust Level

The results of calculating morning and afternoon dust levels in Table 3 and 4 are then mapped to determine the distribution of ambient air dust levels in the City of Yogyakarta as shown in Figure 3(a) and 4(a). In addition, they are presented in graphical form as shown in Figure 5 to determine the highest ambient air dust levels, lowest, and average in the morning and afternoon. The results of the interpolation of dust content in the morning ambient air in Figure 3 show that the distribution of dust content in the very high category is in the range of 0.17000-0.2000 gram/m^3 tends to be found on roads with location code 15. Meanwhile, the distribution of dust content in the category very low in the range of 0.06000-0.09000 gram/m^3 tends to be found on roads with location codes 14, 9, 11, and 6. Overall, the dust content of ambient air in the city of Yogyakarta in the morning is in the low category with a range of 0.09000-0.012000 gram/m^3 which spreads to the south on roads with location codes 3 and 4.

Table 3. Morning Ambient Air Dust Measurement Data

Location Code	Dust content gram/ (30 minutes)	Dust content gram/m^3 (24 hours)
1	0.003	0.128
2	0.003	0.128
3	0.002	0.096
4	0.002	0.096
5	0.003	0.128
6	0.001	0.064
7	0.003	0.128
8	0.003	0.128
9	0.001	0.064
10	0.002	0.096
11	0.001	0.064
12	0.002	0.096
13	0.003	0.128
14	0.001	0.064
15	0.004	0.192
	Average	0.107

Table 4. Data for Evening Ambient Air Dust Measurements

Location Code	Dust content gram/ (30 minutes)	Dust content gram/m^3 (24 hours)
1	0.001	0.064
2	0.001	0.032
3	0.005	0.256
4	0.003	0.128
5	0.003	0.128
6	0.002	0.096
7	0.001	0.064
8	0.002	0.096
9	0.002	0.096
10	0.002	0.096
11	0.001	0.064
12	0.001	0.032
13	0.001	0.064
14	0.003	0.160
15	0.003	0.160
	Rata-rata	0.1024

Interpolation of afternoon ambient air dust levels in Figure 4 shows that the distribution of dust levels in the very high category is in the range of 0.21000-0.26000 gram/m^3 which tends to be found on roads with location code 3. Meanwhile, the distribution of dust levels in the very high category low levels is in the range of 0.03000-0.08000 gram/m^3 which tend to be found on roads with location codes 1, 2, 11, 12, 13, and 7. Overall, the ambient air dust content of Yogyakarta City in the morning is in the high category. The low is in the range of 0.08000-0.12000 grams/m^3 which spreads eastward including on roads with location codes 6, 8, 9, and 10.

Based on Figure 5, the highest ambient air dust content in the morning was 0.19200 gram/m^3 on the road with location code 9. Meanwhile, in the afternoon, it was 0.25600 gram/m^3 on the road with location code 3. Difference in air dust content, the highest ambient in the morning and afternoon was 0.06400 gram/m^3 with the highest dust levels occurring in the afternoon. Apart from that, the lowest ambient air dust content in the morning was 0.06400 gram/m^3 on roads with location codes 6, 9, 11, and 14. Meanwhile, in the afternoon it was 0.03200 gram/m^3 on roads with location codes 2 and 12. The difference between the lowest ambient air dust levels in the morning and afternoon is 0.03200 gram/m^3 with the highest dust levels occurring in the morning. The overall average dust content in the ambient air in the morning was 0.10667 gram/m^3 while in the afternoon it was 0.10240 gram/m^3. There is a difference between the averages in the morning and afternoon of 0.00427 gram/m^3 with the largest average occurring in the morning.

Environmental Conditions Around the Site

Observations were made of environmental conditions around the sampling location because they can influence the circulation and concentration of dust levels in the ambient air. The observation results in Table 5 show that there is vegetation and no clearing at all sampling location points. Meanwhile, based on the presence of tall buildings at the sampling points at location codes 1, 2, 3, and 5 there are no tall buildings.

Table 5. Environmental Conditions Around the Location

Code	The Environment Around the Location		
	Vegetation	Field	Tall Building
1	√	-	-
2	√	-	-
3	√	-	-
4	√	-	√
5	√	-	-
6A	√	-	√
6B	√	-	√
6C	√	-	√
7A	√	-	√
7B	√	-	√
7C	√	-	√
8A	√	-	√
8B	√	-	√
8C	√	-	√
9	√	-	√

Information : "√" = There is, "-" = There isn't any

Meteorological Conditions

Meteorological factors are controlled by measuring them simultaneously with measurements of dust and vehicle volume. The results of measuring meteorological factors can be seen in Table 6 and Table 7.

Table 6. Data for Measuring Morning Meteorological Conditions

Location Code	Temperature (°C)	Humidity (% RH)	Wind Velocity (ms/s)
1	27.2	85	0.54
2	33.1	64.4	1.71
3	27.6	83.3	1.14
4	27.1	83.5	1.75
5	27.2	77.7	1.12
6	37.5	48.6	1.85
7	35.0	53.4	1.40
8	35.1	55.5	1.08
9	28.0	76.2	1.01
10	28.9	72.1	1.83
11	37.6	50.2	1.00
12	28.5	70.1	1.52
13	28.0	71.4	1.09
14	28.4	71.4	1.57
15	31.7	70.7	0.82
Average	30.7	68.9	1.30

Table 7. Data for Measuring Meteorological Conditions in the Afternoon

Location Code	Temperature (°C)	Humidity (% RH)	Wind Velocity (ms/s)
1	32.2	66	10.6
2	29.9	74.2	1.61
3	29.7	72.3	1.42
4	27.9	79.9	1.2
5	30.3	69.2	0.69
6	29.9	67.2	1.44
7	29.2	67.9	1.07
8	29.6	66.0	1.09
9	31.1	66.1	0.56
10	29.3	70.2	1.85
11	28.0	75.9	0.72
12	27.9	66.5	1.05
13	28.1	69.3	0.16
14	27.6	66.9	1.13
15	30.8	67.4	1.95
Average	29.4	69.6	1.77

The results of the interpolation analysis of the morning ambient air temperature distribution in Yogyakarta City in Figure 6 show that the distribution of temperatures in the very high category is in the range 35.45 - 37.54°C, which tends to be found in roads with location code 6. Meanwhile, the distribution of temperatures in the very low category is in the range 27.10 - 29.20°C, which tends to be found on roads with location codes 1, 3, 4, 5, 13, and 14. Overall, the distribution of ambient air temperatures in the city of Yogyakarta in the morning is in the low category at 29.20 - 31.30°C. On the other hand, the results of the interpolation analysis of the distribution of ambient air temperature in the afternoon of Yogyakarta City in Figure 1 and Figure 7(b), show that the temperature distribution in the very high category is in the range of 31.27 - 32.19°C, which tends to be found on roads with location code 1. Meanwhile, the temperature distribution in the very low category is in the range of 27.60 - 28.52°C and tends to be found on roads with location codes 4, 11, 12, 13, and 14. Overall, the distribution of ambient air temperature in Yogyakarta City in the morning is in the low category in the range of 28.52 - 29.44°C and is in the range of 29.44 - 30.36°C.

The results of the interpolation analysis of the distribution of morning ambient air humidity in Yogyakarta City in Figure 8 show that the distribution of very high category humidity is in the range 77.68 - 84.95% RH, which tends to be found on roads with location codes 1, 4 and 3. Meanwhile, the humidity distribution in the very low category is in the range of 48.60 - 55.87% RH, which tends to be found at 6, 7, and 11. Overall, the humidity distribution is in the medium category in the range of 63.14 - 70.41% RH and high in the range of 70.41 - 77.68% RH. On the other hand, the results of the interpolation analysis of the distribution of ambient air humidity in the afternoon of Yogyakarta City in Figure 9, show that the distribution of humidity in the very high category is in the range of 77.12 - 79.90% RH, which tends to be found on roads with location code 4. Meanwhile, the distribution of very low category humidity is in the range of 66.00 - 68.79% RH, which tends to be found on roads with location codes 1, 6, 7, 8, 9, 12, 14, and 15.

The results of the interpolation analysis of the distribution of morning ambient air wind speeds in Yogyakarta City in Figure 10 show that very high category wind speeds are in the range of 1.59-1.85 ms/s, which tend to be found on roads with location codes 10, 4 and 6. Meanwhile, the air speed distribution in the very low category is in the range 0.54-0.80 ms/s, which tends to be found on roads with location code 1. Overall, the wind speed distribution is in the medium category in the range 1.06-1.33 ms/s and high in the range 1,33-1.59 ms/s. On the other hand, the results of the interpolation analysis of the distribution of ambient air speed in the afternoon of Yogyakarta City in Figure 11, show that very high category wind speeds are in the range of 8.49-10.58, which tend to be found on roads with location code 1. Meanwhile, overall, the distribution of very low wind speeds in the range of 0.16-2.24 ms/s tends to be found on roads with location codes 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15.

DISCUSSION

The morning from 5-8 a.m. is called the morning rush period. In this condition, anthropogenic activities occur in the form of community mobilization such as going to work, school, and other activities (8). A similar thing happens in the afternoon, as people mobilize to return to their homes. In the morning, Jl. Magelang 127 Karangwaru Yogyakarta with code 2 and Jl. Laksda Adisucipto 77, Demangan, Gondokusuman, Yogyakarta with code 5 are the roads with the highest vehicle volume. Hal ini dikarenakan Jl. Magelang berfungsi sebagai pintu masuk utama Kawasan D.I Yogyakarta dari utara, menghubungkannya dengan Semarang, Magelang, dan lokasi sekitarnya. On the other hand, there are various tourist attractions on the road, such as Jogja Bay Waterpark, Pelangi Park, Jogja Lagi Monument, Sindu Kusuma Edupark, and Johnston (9). Laksda Adisucipto Street is a primary arterial road connecting Yogyakarta with eastern areas such as Klaten, Solo, and surrounding areas. On the other hand, Laksda Adisucipto Street is located in a shopping center which is often crossed by traffic movements such as private vehicles, goods, and passenger transport which increases the quantity of vehicles and congestion (10). Congestion on Jl. Rear Admiral Adisucipto can affect road performance, one of which is caused by vehicles parking and stopping, the presence of pedestrians crossing, the number of motorized vehicles entering and leaving side roads, and the slow movement of vehicle flow (11). Apart from that, side obstacles and the degree of saturation also influence traffic jams. The side barrier on the Laksda Adisucipto Street Km 4.4 such as street vendors along the sidewalk results in crowds on the section so that traffic becomes narrower. The degree of saturation reaches 3,200 or is in category F, which means it is included in the characteristics of obstructed flow, low speed, long queues, and large obstacles (12). Meanwhile, in the afternoon, the road with the highest vehicle volume is at Jenderal Sudirman 70 Street, Gondokusuman, Yogyakarta with location code 6. This is because this road is a trading area such as restaurants, offices, banking, and hotels. In addition, the enactment of a one-way street on C. Simanjuntak and Jl. Prof. Yohanes Street caused a traffic jam on Jl. General Sudirman. This density can be seen at the Galeria crossroad to the Gramedia crossroad, especially in the morning and afternoon (13).

Analysis of total dust content using the quality standard method showed the average dust content from sampling in the morning was 0.10667 gram/m^3 while in the afternoon it was 0.10240 gram/m^3. The highest levels of air pollution recorded in the morning were 0.19200 gram/m^3 on Jl. RE Martadinata 61. In the afternoon, the highest levels were 0.25600 gram/m^3 on Jl. Bantul 302 in Yogyakarta. Based on Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and

Management, the quality standard for dust in ambient air for TSP is 230 μg/m^3 or 0.00023 gram/m^3 for 24 hours. So the ambient air dust content, both average and highest, exceeds the specified quality standards. The high total dust content is due to the large number of motorized vehicles. One of the factors that influence Total Suspended Particulate (TSP) and Particulate Matter (PM_{10}) dust levels is motor vehicles (14). This is in line with the research was conducted in Surabaya in 2018 resulted in high TSP levels at the Waru Roundabout, Surabaya City of 2.46000 mg/m^3 because the numbers of vehicles at the Waru Roundabout are very high as it connects Sdoarjo, Mojokerto, and Surabaya (15). Apart from that, research on the primary road network of Padang City in 2018 found the quality standard for dust content PM_{10} at peak hours exceeded the quality standard, especially Sudirman Street of 164.38000 μg/m^3 at 00-04 pm due to the increasing number of passing vehicles resulting in the higher PM_{10} concentration (16). The high number of motorized vehicles is in line with the increase in human activity. Human activities affect the concentration of Total Suspended Particulate in particular and air quality in general (17).

Residents who live around the roadside can be exposed to dust levels that exceed quality standards and are more at risk of health impacts. Many recent studies report that more and more people, not only those living along highways but also people living along highways, are experiencing chronic respiratory symptoms, decreased lung function, and asthma (18). Dust particles are air pollution that can coexist with other substances or pollutants (15). Dust particles remain in the air for a relatively long time and then enter the human body through breathing (19). Particulate dust is categorized in Total Suspended Particulate Matter which has a size of 0.10000-30 μm. Total Suspended Particulate Matter is made up of three types: fine, coarse, and super coarse particles. Research was conducted in Bogor in 2021 found that the risk level of Total Suspended Particulates in each sub-district of Bogor City for the male and female population is more than one, which means that there is a health risk in that area, so risk control or management is needed (20). This is in line with research in Semarang in 2018 found that a significant relationship between dust exposure and impaired lung function in street vendors in Jalan Brigjen Sudiarto, Semarang City. As many as 76% of the total respondents who were exposed to dust exceeding quality standards experienced lung function problems. This percentage is higher when compared to respondents who inhale dust below the quality standard, only 33.30% experienced lung problems or it can be said that respondents who inhale dust above the quality standard were twice at risk of experiencing lung function disorders compared to respondents who were exposed to dust below quality standards (21).

At all sampling points vegetation was found. Urban vegetation can improve air quality by capturing and retaining airborne particulates. Particulate accumulation in vegetation leaves is influenced by several parameters such as wind aerodynamics, leaf receptor characteristics, vegetation height, and the pollutant particle model. Roadside green spaces are where relatively low PM concentrations in the atmosphere are highest. Conversely, where green space is relatively higher (e.g. residences and parks), PM concentrations are the lowest (22). The absence of vegetation as a barrier on the sidewalk increases the concentration of PM_{10} by 16.01300 μg/m^3 and Total Suspended Particulate by 8.34100 μg/m^3 (23). In line with the research was conducted in Makassar in 2021, it is known that the concentration of Total Suspended Particulate in the ambient air in Veteran Utara Street Makassar City is below the quality standard of 208.53000 μg/m^3. This is because there are trees on the side of the road and road media along Veteran Utara Street (24). The rest of the particulates on the leaves can cover the cuticles, but most of the particulates that have been captured by vegetation can be suspended back into the air and become air pollutants again (25). According to research was conducted in Mojokerto in 2021, which tested the effectiveness of highway vegetation in absorbing total suspended particulate matter by measuring the levels of total suspended particulates and the volume of vehicles passing on the highway and behind the vegetation, the resulting red shoot plant (*Syzygium oleana*) can absorb Total Suspended Particulate of 93.19150 μg/Nm^3 or 32.65% and Ketapang can absorb 53.37000 μg/Nm^3 (26). These plants can be used as road vegetation to absorb TSP in the city of Yogyakarta.

The existence of buildings at the sampling location plays a role in influencing the process of dispersion of dust content in ambient air. As many as 73% of the sampling locations have tall buildings. Wind carries dust pollutants into buildings, the wind will experience turbulence which causes pollutants to concentrate in one place because buildings can affect wind direction, wind speed, and air stability. The nature of wind flow is determined by the shape of the building which can facilitate or inhibit the natural flow of wind. Based on research analyzing the vertical movement of particles due to the pile effect on high-rise buildings, it was found that the concentration of particulates in the vertical axis decreased toward the upper floors due to wall deposition (27). In addition, in a multi-mass building, the mass layout affects the level of air pollution. A narrow area and a little open space will make it difficult for the distribution of pollutants by the wind and cause hotspots in the area. Meanwhile, in large and open areas, it can facilitate wind circulation for the process of diffusing pollutants and preventing the accumulation of pollutants in one place (28).

Meteorological factors can influence ambient air dust levels. Meteorological factors (temperature, humidity, wind speed) affecting cities have a major impact on particulate concentrations (29) and can simultaneously affect the total dust air quality and explain the dust-bound variable of 86% (30). Wind speed can determine the direction of distribution and accumulation of dust concentration in the ambient air. The temperature factor also determines the concentration of dust in the ambient air. The average temperature and dust levels in the morning are higher than in the afternoon. The average temperature in the morning is 30.70 with a dust content of 0.10667 gram/m^3. Meanwhile, in the afternoon, the average temperature was 29.43 with a dust content of 0.10240 gram/m^3. The higher the air temperature, the higher the dust concentration on ambient air quality (31). High temperatures will cause the soil surface to become dry which results in increased dust concentrations. In addition, an increase in temperature causes a decrease in humidity (32). High humidity affects pollutants in the air (31). High humidity causes levels of water molecules to react with pollutants in the air to form hazardous compounds or secondary pollutants. The higher the humidity, the greater the potential for dust to agglomerate which allows precipitation to occur and will settle to the ground under the influence of gravity (32). Low category air humidity (<60%) affects the concentration of ambient air quality, this can increase the concentration of Total Suspended Particulate (31).

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CONCLUSION

The highest average vehicle volume in the City of Yogyakarta occurs in the afternoon while the highest total dust content occurs in the morning and the distribution of total dust content both on average and by interpolation exceeds the quality standard based on Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Implementation of Environmental Protection and Management. Researchers recommend that future studies measure dust levels based on size.

REFERENCE

1. Central Bureau of Statistics of Yogyakarta. Yogyakarta in Number 2022. Yogyakarta: Central Bureau of Statistics of Yogyakarta; 2022. https://yogyakarta.bps.go.id/publication/2022/02/25/05661ba4fe09161192c3fc42/provinsi-daerah-istimewa-yogyakarta-dalam-angka-2022.html
2. Central Bureau of Statistics of Yogyakarta. Yogyakarta in Number 2023. Yogyakarta: Central Bureau of Statistics of Yogyakarta; 2023. https://jogjakota.bps.go.id/publication/2023/02/28/9510c8b16be475ce64f99471/kota-yogyakarta-dalam-angka-2023.html
3. IQAir. World Air Quality Report by IQAir 2021. Jakarta: IQAir; 2021. https://www.iqair.com/id/newsroom/laporan-kualitas-udara-dunia-iqair-2021
4. Sembiring ETJ. Risiko Kesehatan Pajanan $PM_{2,5}$ di Udara Ambien pada Pedagang Kaki Lima di Bawah Flyover Pasar Pagi Asemka Jakarta. *J Tek Lingkung*. 2020;26(1):101–120. https://doi.org/10.5614/j.tl.2020.26.1.7
5. Uniplaita J, Mangangka IR, Legrans RRI. Studi Penurunan Kualitas Udara Ambien Akibat Debu dari Kendaraan Bermotor (Studi Kasus: Jl. R. W. Monginsidi Depan Kawasan Bahu Mall Manado). *Tekno*. 2021;18(76):237–248. https://ejournal.unsrat.ac.id/index.php/tekno/article/view/31677
6. Sugiyono. Statistika untuk Penelitian. Bandung: Alfabeta; 2019.
7. Serlina Y. Pengaruh Faktor Meteorologi terhadap Konsentrasi NO_2 di Udara Ambien (Studi Kasus Bundaran Hotel Indonesia DKI Jakarta). *J Serambi Eng*. 2020;5(3):1228–1235. https://ojs.serambimekkah.ac.id/index.php/jse/article/view/2146/1757
8. Utama YW, Permadi DA. Distribusi Temporal Konsentrasi PM10 Menggunakan Alat Particle Plus EM-10000. *J Ecolab*. 2021;15(1):45–52. http://dx.doi.org/10.20886/jklh.2021.15.1.45-52
9. Nugraha WS. Daftar Wisata di Sekitar Jalan Magelang di Yogyakarta. Yogyakarta: Tribun Jogja Wiki; 2020. https://tribunjogjawiki.tribunnews.com/2020/04/07/daftar-wisata-di-sekitar-jalan-magelang-di-yogyakarta
10. Karim MS, Handayani AT, Astutik HP. Kinerja Ruas Jalan Saat Kondisi New Normal (Studi Kasus Jalan Laksda Adisutjipto, Yogyakarta KM 6,3-6,8). *Equilib.* 2021;2(1):13–20. https://journal.itny.ac.id/index.php/equilib/article/view/2127
11. Hidayat AW. Pengaruh Hambatan Samping Terhadap Kinerja Jalan (Studi Kasus Ruas Jalan Depan Pasar Mayong Jepara). *INERSIA Informasi dan Ekspose Has Ris Tek Sipil dan Arsit*. 2020;16(2):171–178. https://doi.org/10.21831/inersia.v16i2.36902
12. Oktavila, Sulistyorini D, Sutrisno W. Evaluasi Kinerja Ruas Jalan Laksda Adisucipto KM 4,4 Yogyakarta Menggunakan Metode PKJI 2014.

Skripsi. Yogyakarta: Universitas Sarjanawiyata Tamansiswa; 2022.

13. Hasanudin U. Lalu Lintas Jogja: Jalan Jenderal Sudirman Diusulkan Dua Arah. Yogyakarta: Harian Jogja; 2014. https://jogjapolitan.harianjogja.com/read/2014/10/13/510/543853/lalu-lintas-jogja-jalan-jenderal-sudirman-diusulkan-dua-arah
14. Fitriyah F, Indriyani YS, Sumiardi A. Pengaruh Kendaraan Bermotor Terhadap Pencemaran Udara di Kecamatan Ciruas Serang Banten. *J Sustain Civ Eng*. 2022;04(02):89–98. https://doi.org/10.47080/josce.v4i02.2206
15. Ma'rufi I. Analisis Risiko Kesehatan Lingkungan (SO_2, H_2S, NO_2 dan TSP) Akibat Transportasi Kendaraan Bermotor di Kota Surabaya. *MPI (Media Pharm Indones)*. 2018;1(4):189–196. https://doi.org/10.24123/mpi.v1i4.770
16. Gunawan H, Ruslinda Y,Bachtiar SV, Dwinta A. Model Hubungan Konsentrasi Particulate Matter 10 PM (PM_{10}) di Udara Ambien dengan Karakteristik Lalu Lintas di Jaringan Jalan Primer Kota Padang. *Semin Nas Sains dan Teknol*. 2018;17(15):1–11. https://jurnal.umj.ac.id/index.php/semnastek/article/view/3557
17. Nuraini TA, Permana DS, Satyaningsih R, Anggraeni R, Aldrian E. Comparison of Total Suspended Particulate (TSP) Measurement in Urban and Suburban Areas of Bali during Nyepi Day 2015. *Forum Geogr*. 2020;33(2):173–183. https://doi.org/10.23917/forgeo.v33i2.8670
18. Zhao Y, Zhao C. Concentration and Distribution Analysis of Heavy Metals in Total Suspended Particulates along Shanghai-Nanjing Expressway. *Procedia Environ Sci*. 2012;13(2011):1405–1411. http://dx.doi.org/10.1016/j.proenv.2012.01.133
19. Hadi BS. Pemantauan Kualitas Udara Ambien PM_{10} dan Risiko Kesehatan Terhadap Masyarakat di Kabupaten Sleman, Daerah Istimewa Yogyakarta. Skripsi. Yogyakarta: Universitas Islam Indonesia 2021.
20. Ihsan IM, Yani M, Hidayat R, Permatasari T. Fluktuasi Cemaran Udara Partikulat dan Tingkat Risikonya terhadap Kesehatan Masyarakat Kota Bogor. *J Teknol Lingkung*. 2021;22(1):38–47. https://doi.org/10.29122/jtl.v22i1.4439
21. Fatimah CL, Darundiati YH, Joko T. Hubungan Kadar Debu Total dan Masa Kerja dengan Gangguan Fungsi Paru pada Pedagang Kaki Lima di Jalan Brigjen Sudiarto Kota Semarang. *J Kesehat Masy*. 2018;6(6):49–60. https://ejournal3.undip.ac.id/index.php/jkm/article/view/22156
22. Chowdhury AI, Uddin MJ, Baul TK, Akhter J, Nandi R, Karmakar S, et al. Quantifying the Potential Contribution of Urban Trees to Particulate Matters Removal: A study in Chattogram City, Bangladesh. *J Clean Prod*. 2022;380(135015):1-8. https://doi.org/10.1016/j.jclepro.2022.135015
23. Oktaviani E. Paparan Particulate Matter (PM_{10}) dan Total Suspended Particulate (TSP) di Trotoar Beberapa Jalan Kota Surabaya. Thesis. Surabaya: Institut Teknologi Sepuluh November; 2018.
24. Safaat AIFW, Aly SH, Harusi NMR. Analisis Polutan Total Suspended Particulate (TSP) Pada Jalan Arteri Divided di Kota Makassar. *Univ Indones.* 2021;9(2):43–54. https://ppjp.ulm.ac.id/journal/index.php/jukung/article/download/17571/9473
25. Sari YW, Darnas Y, Hamdan AM. Karakterisasi Sifat Magnetik Daun untuk Analisa Polusi Udara: Sebuah Tinjauan Ulang. *J Serambi Eng*. 2020;5(4):1367–1377. https://doi.org/10.32672/jse.v5i4.2324
26. Utomo HP, Ratnawati R. Evektivitas Vegetasi untuk Penurunan Kadar Karbon monoksida (CO) dan Nitrogen Dioksida (CO_2). *J Tek Waktu*. 2021;19(2):38–43. https://doi.org/10.36456/waktu.v19i01.3638
27. Park S, Cai Y, Lim H, Song D. Analysis of Vertical Movement of Particulate Matter due to The Stack Effect in High-Rise Buildings. *Atmos Environ*. 2022;279(1):119113. https://doi.org/10.1016/J.ATMOSENV.2022.119113
28. Wibowo NA, Hadiwono A. Air-Chitecture: Sebuah Desain Bangunan dengan Purifikasi Udara Secara Teknis dan Puitis Dalam Konteks Berhuni. *J Sains Teknol Urban Perancangan Arsit*. 2021;3(1):589-600. https://doi.org/10.24912/stupa.v3i1.10748
29. Yáñez MA, Baettig R, Cornejo J, Zamudio F, Guajardo J, Fica R. Urban Airborne Matter in Central and Southern Chile: Effects of Meteorological Conditions on Fine and Coarse Particulate Matter. *Atmos Environ*. 2017;161(1):221–234. https://doi.org/10.1016/j.atmosenv.2017.05.007
30. Sulistiani I, Partama IGY, Surata SPK, Sumantra IK. Dinamika Kualitas Udara Ambien Selama Masa Pandemi Covid-19 di Kawasan Indonesia Tourism Development Corporation Nusa Dua Bali. *ECOTROPHIC*: *J Ilmu Lingkung*. 2021;15(1):124-137. https://doi.org/10.24843/ejes.2021.v15.i01.p11
31. Ibrahim Z, Boekoesoe L, Lalu NAS. Identifikasi Kualitas Udara Ambien Disekitar Wilayah Kota Gorontalo. *Public Heal Surveilance Rev*. 2022;1(1):24–33. https://ejurnal.ung.ac.id/index.php/phsr/article/view/16414
32. Fauziah DA, Rahardjo M, Astorina N, Dewanti Y. Analisis Tingkat Pencemaran Udara di Terminal Kota Semarang. *J Kesehat Masy*. 2017;5(5):561–570. http://ejournal3.undip.ac.id/index.php/jkm