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Analysis of vehicle emissions due to traffic on the Tambun Bungai Street Palangka Raya

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ABSTRACT

Tambun Bungai street is located between Ahmad Yani and Diponegoro street. It has a significant level of congestion due to the presence of several schools, view place of worship and District Public Hospital. Motor vehicle activity produces exhaust gas emissions that cause air pollution resulting in a decrease in air quality. The purpose of this research to determine the magnitude of motor vehicle exhaust gas emissions in Tambun Bungai street and compare the results of the analysis of total vehicle emissions with permitted air quality standards. The methods are traffic counting survey and spot speed survey, then the analyze using an empirical calculation. Based on the results of the analysis it is known that the largest emissions of light vehicles occurring on Tambun Bungai street are CO of 1783,15 ppm and HC of 229,95 ppm at 07.45-08.00, PM of 7,14 $\mu g/m^3$ and NOx of 29,68 pphm at 07.00-07.15. Then for the largest emissions of heavy vehicles occurred on Tambun Bungai street are CO of 0,63 ppm, HC of 0,28 ppm, PM of 257,80 $\mu g/m^3$ and NOx of 82,71 pphm at 07.00-07.15. Overall the result of emissions total that compared to permitted quality standard shows that the results of the analysis of each type of pollutant exceeded the permissible air quality standards. These results can illustrate the amount of pollution that occurs and has exceeded the specified threshold so that the government can make policies that can be minimized it.

ABSTRAK

Jalan Tambun Bungai berada diantara Jalan Ahmad Yani dan Jalan Diponegoro. Jalan ini memiliki tingkat kepadatan yang cukup signifikan karena adanya beberapa sekolah, tempat ibadah dan Rumah Sakit Umum Daerah. Aktivitas kendaraan bermotor menghasilkan emisi gas buang yang menyebabkan pencemaran udara sehingga mengakibatkan menurunnya kualitas mutu udara. Tujuan dari penelitian ini untuk mengetahui besarnya emisi gas buang kendaraan bermotor di Jalan Tambun Bungai dan membandingkan hasil analisis emisi kendaraan total dengan standar kualitas udara yang diizinkan. Metode pada penelitian ini yaitu survey lalu lintas dan survei kecepatan kendaraan, kemudian dianalisis menggunakan hitungan rumus empirik. Berdasarkan hasil analisis diketahui besaran emisi kendaraan ringan tertinggi yang terjadi di ruas Jalan Tambun Bungai yaitu CO sebesar 1783,15 ppm dan HC sebesar 229,95 ppm pada pukul 07.45-08.00, PM sebesar 7,14 $\mu g/m^3$ dan NOx sebesar 29,68 pphm pada pukul 07.00-07.15. Kemudian untuk besaran emisi kendaraan berat tertinggi yang terjadi di ruas Jalan Tambun Bungai yaitu CO sebesar 0,63 ppm, HC sebesar 0,28 ppm, PM sebesar 257,80 $\mu g/m^3$ dan NOx sebesar 82,71 pphm pada pukul 07.00-07.15. Secara keseluruhan hasil analisis emisi kendaraan total yang dibandingkan dengan standar kualitas udara yang diizinkan menunjukkan bahwa hasil analisis masing-masing jenis polutan ternyata melebihi baku mutu udara yang diizinkan. Hal tersebut dapat menggambarkan besarnya polutan yang terjadi dan sudah melebihi ambang batas yang ditentukan sehingga pemerintah dapat membuat kebijakan yang bisa meminimalisir besarnya polutan yang terjadi.

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1. Introduction

The people of the Palangka Raya city were 305.907 [1]. The increase in population will be accompanied by the increase in the number of vehicles. By 2021 the number of vehicles in Palangka Raya was 345.510 and by 2022 the number of vehicle increased to 360.347 units [1]. This is in line with the results of research that states that in European countries the increase in the number of vehicles is proportional to the population [2]. The increasing number of motor vehicles operating on the roads, it will cause increases in the concentration of pollutants so it is concerned that harmful to human health and affect the air quality when exceeding the specified thresholds [3]. Motor vehicles are a major source of urban pollution and account for 70% of NOx emissions, 52% of VOC emissions and 23% of particulate matter [4]. Air pollution from the transport sector has contributed 80% followed by emissions from industry, forest fires and household activities [5]. This shows that the transport sector has the largest emission contribution to air pollution [6]. One of the busiest motor vehicle activities in Palangka Raya is the Tambun Bungai street. This road has significant motor vehicle activity. Apart from being the main link between A.Yani Street and Diponegoro Street, along the street there are public facilities such as schools, places of worship, and district hospitals. Motor vehicle activity produces exhaust gas emissions that cause air pollution resulting in a decrease in air quality [7]. The air pollution that occurs will have a negative impact on health and the environment. The negative impact of this transportation activity is the emission of exhaust gases emitted from vehicle smoke that is toxic to the air around it [8]. Toxic or commonly called water pollutants are the largest source of air pollution in the atmosphere, mostly produced by motor vehicles [9]. In the legislation to anticipate this, the Government of Indonesia has enacted and promulgated Law No. 22 of 2009 on Traffic and Road Transportation to Motor Vehicle Users that Produce Air Pollution, in order to suppress the enormous amount of air pollution using Fossil Fuel (Fossil Fuels) to each vehicle user [10]. But it turns out that in its application it has not been able to mitigate the impact. Based on the above description, it is necessary to study the emissions of vehicles due to traffic on the Tambun Bungai street. The purpose of this research to determine the magnitude of motor vehicle exhaust gas emissions in Tambun Bungai street and compare the results of the analysis of total vehicle emissions with permitted air quality standards. The results of the research are expected to be used as a basis in making policies to minimize the size of pollutants occurring in Palangka Raya.

2. Research Methodology

2.1. Data Collection

The data used in this study are primary and secondary data. Primary data on this study was obtained from a traffic survey conducted in the morning from 06.00-08.00 which includes geometric data of roads, vehicle volume data and vehicle speed data along Tambun Bungai street. Secondary data is spatial data on Bungai Tambun street area.

2.2. Vehicle Volume Analysis

Traffic volume is the number of cars passing a particular location on a particular road in a given time, usually expressed in vehicle/hour [11]. The most crucial element in traffic engineering is the flow of traffic, which is basically a measurement of the amount of movement per unit of time at some particular place. Only one form of transport mode, such as people, vehicles, buses, or freight trains, or groups of mixed modes, can be included in the total number of movements [12]. Vehicle volume survey results are categorized into three types of vehicles: light vehicles, heavy vehicles, and motorcycles. According to MKJI (1997) [13], the number of cars that cross a point or a fictitious line on a road within a certain period of time is called a traffic stream. Average Annual Day Traffic Measurement (LHRT), Vehicle/Hour (Qkend), smp/hour (Qsmp), or daily flow. The following formula can be used to determine the volume or flow of traffic if N cars pass line AA1 at time T:

$$Q = \frac{N}{T} \quad (1)$$

2.3. Spot Speed Analysis

The vehicle speed data is obtained from the spot speed survey. Spot speed is the speed of the vehicle at the time of passing a specific point on the highway [14]. In this study, the spot speed survey was carried out within 30 meters and calculated using a stopwatch for two hours with a 15-minute interval.

2.4. Vehicle Emissions Analysis

Exhaust gas emissions are pollutants that pollute the air generated by vehicle exhaust gasses [15]. Vehicle emissions are the exhaust gases resulting from the combustion of fossil fuels such as oil, natural gas, or coal that come out of the vehicle and are discharged into the air [16]. The number of cars that cross a point or a fictitious line on a road in a given period of time is called a traffic stream. Average Annual Day Traffic Measurement (LHRT), Vehicle/Hour (Qkend), smp/hour (Qsmp), or daily flow On the contrary, ambient air is the unlimited air that exists on the earth's surface in the troposphere layer. It is necessary and affects the well-being of humans, other living creatures, and other environmental components. To study the data and determine the amount of exhaust gases emitted by motor vehicles (CO, HC, NOx, and PM), we will continue to use the empirical method to calculate the total emissions of motor vehicle exhaust gases (CO, HC, NOx, and PM) based on such results. Field data and survey tests have been carried out. As for the empirical calculation formula used, it is as follows [7]:

a. Light Vehicle Traffic Currents :

$$Ekr = Vr \times FPKr/1000 \times FKKKr \quad (2)$$

b. Heavy Vehicle Traffic Currents :

$$Ekb = Vb \times FPKb/1000 \times FKKKb \quad (3)$$

c. Calculation of total emission :

Etotal = E Kr + E Kb, for each pollutants (4)

Where :

Vr = Vehicle per hour in light car traffic

Vb = (Vehicle/hour) Volume of traffic of solid vehicles

FPKr = For each category of pollution, pollutants generated by light vehicles (Table 1)

FPKb = Pollution factor of heavy vehicles for each polluting category (Tabel 2)

FKKKr = For each type of pollutant, the conversion factor of the speed of light vehicles is listed in Table 3

FKKKb = For every type of contamination, the velocity converter of the heavy vehicles is shown in Table 4

The pollutant value factor as an estimate of the volume of traffic exhaust gas emissions on the highway can be seen in Table 1 and 2. Whereas the vehicle speed conversion value can be found in Table 3 and 4 below.

Table 1. Pollution level based on distance per 1000 vph (Light Vehicle)

Distance Pollutant (m)	Light Vehicles (LV)			
	CO (ppm)	HC (ppb)	NO_x (ppb)	PM ($\mu g/m^3$)
5	0,505	98,5	200,4	6,56
10	0,478	93,2	189,1	6,18
15	0,410	80,0	162,2	5,34
20	0,350	68,4	138,7	4,58
25	0,301	58,7	119,3	3,96
30	0,260	50,7	103,2	3,44
35	0,226	44,1	89,0	2,98
40	0,198	38,4	78,4	2,64
45	0,173	33,7	68,8	2,32
50	0,152	29,6	60,6	2,05

Table 2. Pollution level based on distance per 1000 vph (Heavy Vehicle)

Distance Pollutant (m)	Light Vehicles (LV)			
	CO (ppm)	HC (ppb)	NO_x (ppb)	PM ($\mu g/m^3$)
5	0,370	46,39	909,8	177,8
10	0,350	43,90	858,8	167,5
15	0,300	37,68	736,4	144,7
20	0,356	32,22	629,7	124,1
25	0,220	27,65	541,6	107,3
30	0,190	23,88	468,5	93,2
35	0,165	20,77	407,7	80,8
40	0,145	18,09	355,9	71,5
45	0,127	15,87	312,4	32,9
50	0,111	13,94	275,1	55,6

Table 3. Speed Conversion Factor for Air Quality Assessment (Light Vehicle)

Speed (kph)	Light Vehicles (LV)			
	CO (ppm)	HC (ppb)	NO_x (ppb)	PM ($\mu g/m^3$)
5	20,53	15,45	3,51	2,21
10	11,57	9,29	1,99	1,72
15	8,30	6,99	1,46	1,50
20	6,48	5,66	1,19	1,36
25	5,25	4,74	1,02	1,26
30	4,34	4,04	0,91	1,17
35	3,63	3,48	0,83	1,10
40	3,05	3,00	0,77	1,04
45	2,57	2,61	0,74	1
50	2,17	2,26	0,71	0,96

Table 4. Speed Conversion Factor for Air Quality Assessment (Heavy Vehicle)

Speed (kph)	Light Vehicles (LV)			
	CO (ppm)	HC (ppb)	NO_x (ppb)	PM ($\mu g/m^3$)
5	4,05	15,01	2,15	2,94
10	3,45	7,85	1,88	2,10
15	2,93	5,38	1,65	1,71
20	2,49	4,09	1,44	1,46
25	2,12	3,28	1,26	1,28
30	1,80	2,72	1,10	1,14
35	1,63	2,30	1,06	1,03
40	1,43	1,98	0,99	0,95
45	1,24	1,72	0,92	0,87
50	1,06	1,52	0,85	0,82

After obtaining the results of the analysis of the volume of total vehicle emissions, then will compare the result of such analysis with the air quality standards permitted based on table 5 below [7].

Table 5. Air Quality Standart

No	Pollutant	Boundary
1	Particulate matter < 10 μm	150 $\mu g/m^3$ – 24 hr
2	Carbon monoxide	25 ppm (1 hour maximum)
3	Nitrogen dioxide	16 pphm (1 hour maximum)
4	Hydrocarbon	0,25 ppm – 3 hr

Where:
$\mu g/m^3$ = Micrograms per cubic meter
Ppm = Parts per million
Pphm = Part per hundred million

3. Results and Discussion

3.1. Traffic Volume of Tambun Bungai Street

Table 6. Vehicle Volume

Time		HV	LV	MC	Total (Vehicle/hour)
Morning	06.00-06.15	0	74	314	388
	06.15-06.30	1	94	398	493
	06.30-06.45	0	109	515	624
	06.45-07.00	3	131	593	727
	07.00-07.15	6	161	589	756
	07.15-07.30	4	156	575	735
	07.30-07.45	3	163	620	786
	07.45-08.00	2	182	664	848
	Total	**19**	**1070**	**4268**	**5357**

Based on table above, it can be determined that there are 5357 vehicles crossing Tambun Bungai street per hour, which includes 19 high vehicle, 1070 light vehicle, and 4268 motorcycle. The table above also shows that Tambun Bungai street has the peak hours between 07.45- 08.00 with the number of vehicles crossing as many as 848 vehicle per hour.

3.2. Vehicle Emissions

Based on the results of the volume survey carried out then the data can be used in empirical calculations to obtain the emission values generated as follows.

Table 7. Light Vehicle Emissions

Time	CO (ppm)	HC (ppm)	PM $\mu g/m^3$	NOx (pphm)
06.00-06.15	399,13	51,14	0,00	0,00
06.15-06.30	1093,97	140,78	1,58	6,40
06.30-06.45	1136,36	145,71	0,00	0,00
06.45-07.00	1453,39	186,22	4,12	17,08
07.00-07.15	1254,97	160,87	7,14	29,68
07.15-07.30	1225,14	157,05	4,76	19,79
07.30-07.45	654,85	83,93	1,77	7,39
07.45-08.00	1783,15	229,95	3,11	12,49
Total	**9000,95**	**1155,66**	**22,48**	**92,83**

Based on the table above it can be seen that the highest emissions of light vehicles occurred at the impact 07.45-08.00 with CO 1783,15 ppm, HC 229,95 ppm, PM 3,11 $\mu g/m^3$and NOx 12,49 pphm. Here's the analysis of the calculation of the volume of emissions of light vehicles at 07.45-08.00:

a. Use light vehicle (Qr) currents that have been converted to motorcycles for CO and HC types of pollutants
b. Find the light vehicle pollution factor (FPKr) from Table 1 by means of interpolation, then obtained :
   CO = 0,05 ppm
   HC = 0,0089 ppm
   PM = 0,73 $\mu g/m^3$
   NOx = 1,91 pphm
c. Find the conversion factor of the speed of light vehicles for each type of pollutant (FKKKr) Table 3 by means of interpolation, then obtain :
   CO = 0,05 ppm
   HC = 0,0089 ppm
   PM = 0,73 $\mu g/m^3$
   NOx = 1,91 pphm
d. Calculation of emission volumes of light vehicles for each type of pollutant (Ekr) :
   CO = 1783,15 ppm
   HC = 229,95 ppm
   PM = 3,11 $\mu g/m^3$
   NOx = 12,49 pphm

Table 8. Heavy Vehicle Emissions

Time	CO (ppm)	HC (ppm)	PM $\mu g/m^3$	NOx (pphm)
06.00-06.15	0,00	0,00	0,00	0,00
06.15-06.30	0,14	0,06	56,43	18,38
06.30-06.45	0,00	0,00	0,00	0,00
06.45-07.00	0,36	0,16	148,50	47,60
07.00-07.15	0,63	0,28	257,80	82,71
07.15-07.30	0,42	0,19	171,86	55,14
07.30-07.45	0,16	0,07	64,15	20,55
07.45-08.00	0,31	0,16	137,41	40,23
Total	**2,01**	**917,69**	**836,15**	**2646,08**

Based on the table above it can be seen that the highest emissions of heavy vehicle occurred at the impact 07.00-07.15 with CO 0,63 ppm, HC 0,28 ppm, PM 257,80 $\mu g/m^3$and NOx 82,71 pphm. Here's the analysis of the calculation of the volume of emissions of heavy vehicle at 07.00-07.15:

a. Find the light vehicle pollution factor (FPKb) from Table 2 by means of interpolation, then obtained :
   CO = 0,04 ppm
   HC = 0,0042 ppm
   PM = 19,80 $\mu g/m^3$
   NOx = 8,67pphm
b. Find the conversion factor of the speed of light vehicles for each type of pollutant (FKKKb) Table 4 by means of interpolation, then obtain :
   CO = 2,99 ppm
   HC = 11,09 ppm
   PM = 2,17 $\mu g/m^3$

NOx = 1,59 pphm

c. Calculation of emission volumes of light vehicles for each type of pollutant (Ekb) :

CO = 0,31 ppm

HC = 0,16 ppm

PM = 137,41 $\mu g/m^3$

NOx = 40,23 pphm

Table 9. Total Vehicle Emissions

Time	CO (ppm)	HC (ppm)	PM $\mu g/m^3$	NOx (pphm)
06.00-06.15	399,13	51,14	0,00	0,00
06.15-06.30	1094,11	140,84	58,01	24,78
06.30-06.45	1136,36	145,71	0,00	0,00
06.45-07.00	1453,75	186,38	152,62	64,67
07.00-07.15	1255,60	161,15	264,94	112,39
07.15-07.30	1225,56	157,23	176,62	74,93
07.30-07.45	655,01	84,00	65,93	27,94
07.45-08.00	1783,46	230,11	140,52	52,72
Total	**9002,97**	**1156,57**	**858,63**	**357,43**
Permitted quality standards	**< 25**	**< 0,25**	**< 16**	**< 150**

After an analysis of the magnitude of emissions of light vehicles and heavy vehicles, then proceed with the calculation of the total emission of vehicle exhaust gases for each type of pollutant as follows. Total vehicle emissions at 07.45-08.00 calculated with equation (4):

CO = 1783,15 + 0,31 = 1783,46 ppm

HC = 229,95 + 0,16 = 230,11 ppm

PM = 3,11 + 137,41 = 140,52 $\mu g/m^3$

NOx = 12,49 + 40,23 = 52,72 pphm

Based on the above data it is known that the total vehicle emissions of each of the largest pollutants that CO 1783,46 ppm, HC 230,11 ppm at 07.45-08.00, while PM of 264,94 $\mu g/m^3$ and NOx of 112,39 at 07.00-07.15. Then comparison of the total emission analysis results with the overall permitted quality standard for each pollutant exceeding the permitted threshold.

4. Conclusion

Based on the analysis that has been done that the largest emissions of light vehicles occurring on Tambun Bungai street are CO of 1783,15 ppm and HC of 229,95 ppm at 07.45-08.00, PM of 7,14 $\mu g/m^3$ and NOx of 29,68 pphm at 07. 00-07.15. Then for the largest emissions of heavy vehicles occurred on Tambun Bungai street are CO of 0,63 ppm, HC of 0,28 ppm, PM of 257,80 $\mu g/m^3$ and NOx of 82,71 pphm at 07.00-07.15. Overall the result of emissions total that compared to permitted quality standard shows that the results of the analysis of each type of pollutant exceeded the permissible air quality standards.

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