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Estimation of CO vehicular emission on arterial roads in Makassar City based on Caline-4

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Abstract. Transportation is one of the most important and strategic of basic needs in daily life. Increased the use of motor vehicles and energy consumption in cities give an impact on air pollution, traffic jam, and public health disorder. The purpose of this research is estimate of Carbon Monoxide (CO) pollutants received in receptors on Arterial Roads in Makassar City. This research was conducted in A.P. Pettarani, Sultan Alauddin, Urip Sumoharjo, and Perintis Kemerdekaan road in peak hour of the morning, afternoon, and evening. Analysis of measurement data is using software WRPLOT View and CALINE-4. The result showed that the highest estimation of CO pollutant in A.P. Pettarani road is KFC receptors with 4,3 ppm, in Sultan Alauddin its happen in Polsek Rappocini with 3,8 ppm, in Urip Sumoharjo its happen in Ridha Allah Mosque with 1,4 ppm, and STIKES Nusantara receptors in Perintis Kemerdekaan road is the place with the highest CO value pollutant estimates, that is 4,4 ppm.

1. Introduction

Makassar city is one of the centers of strategic area development in Eastern Indonesia. In the last decade, almost all major cities in Indonesia have experienced an unusually high number of motor vehicles, including Makassar. This has and still has an impact on road and traffic network performance, such as increasing the degree of saturation and decreasing traffic velocity and also environmental impacts, increasing exhaust gas pollution and increasing traffic noise traffic [1, 2]. Moreover, this condition has transformed the behavior of traffic, from homogeneous traffic to heterogeneous traffic [3].

There is still a lack of studies in Indonesia focusing on the distribution of emissions and the huge of their impacts on the surrounding environment. Previous studies that were conducted still tend to the analysis of vehicle emissions data on idle and moving condition. In 2013, research was conducted based on vehicle emissions analysis in mobile [2]. As for other studies that have discussed the spread of pollutants dispersed in the air but did not discuss further the pattern of distribution and its effects on environmental conditions around the road.

Based on this background, this research is conducted to develop the research that has been done before and to know the pattern of distribution and the estimated impact of pollutants received in the environment. The estimation resulted from this research is the prediction of the amount of pollutant impact in Arterial Road in Makassar City. One method that can be used is by using the CALINE-4 modeling used in this study. The advantage of this CALINE-4 model is that we can estimate the distribution of pollutants and their magnitude of impacts on the environment around the observation site.

2. Research Purpose

This research has a purpose of estimating the amount of Carbon Monoxide (CO) emissions received by each receptor in the Arterial Road on Makassar City.

3. Literature Study

3.1 Motor vehicle emissions.

Transportation emissions are emissions or discharges of flue gases originating from the transportation sector. Motor vehicles type according to Government Regulation No. 55 of 2012, namely: 1) Motorcycles; 2) Passenger Car; 3) Bus;4) Car Goods; and 5) Special Vehicles.

Pollutants that are particularly present in vehicle exhaust gases are carbon monoxide (CO), various hydrocarbon compounds, various nitrogen oxides (NOx), sulfur (SOx), and dust particulates including lead (PB). Certain fuels, such as hydrocarbons and organic leads, are released in the atmosphere due to evaporation from the fuel system [4].

The value of the emission factor used is the vehicle's exhaust emission factor for the metropolitan city, and big city in Indonesia determined based on vehicle category based on the Regulation of the State Minister of Environment Number 12 the Year 2010 on the Implementation of Air Pollution Control in the Region. The value of emission factor can be seen in Table 1:

Table 1. Emission Factor Value

Category	CO	NO_x	CO_2	SO_2
	g/km	g/km	g/kg BBM	g/km
Motorcycle	14	0,29	3180	0,008
Car (gasoline)	40	2	3180	0,026
Car (Solar)	2,8	3,5	3172	0,44
Car (other fuel)	32,4	2,3	3178	0,11
Bus	11	11,9	3172	0,93
Truck	8,4	17,7	3172	0,82

Source: Minister of Environment Regulation No.12/2010 [5]

The following equation can determine the emission quantity:

$$q = \frac{\sum_{i=1}^{n}(EF_i \times V_i)}{T} \quad (1)$$

where:

q = Emission quantity (gram/ km)
EF = Emission factor (gram/ km)
V = Volume of vehicles
i = Type of vehicles
T = Vehicles Total

3.2 Windrose.

Wind is the movement of air from high pressure to low pressure regions with varying speeds, moving horizontally or vertically with varying speeds and fluctuating dynamically. The movement of the whole air is a combination of solar energy, earth rotation, and earth's gravity. Winds cause massive pollutant displacement; pollutant concentrations are visible higher in areas that directed to wind from the source than opposite direction from source. Wind speeds generally increase in proportion to the increase in altitude, and the higher the wind speed, the lower the pollutant concentration (dilution effect) [6]. Wind rose is generally a circle consisting of a central part that shows information on the occurrence of calm wind, a number of lines drawn from the center of the circle representing the direction of the wind and direction in accordance with the direction from which the wind blows, the length of each line that states the frequency of the wind from the direction in question, as well as wind velocity variations represented by the line shapes depicted in the legend of the wind, rose [7].

3.3 Dispersion model CALINE-4.

CALINE-4 is a line air quality model developed by the California Department of Transportation (Caltrans). The model is run based on the Gaussian diffusion model and uses the concept of mixing zone to estimate the dispersion of pollutants near the highway with several important parameters, such as source power (traffic volume per link and emission factor), meteorology, and site geometry. CALINE-4 can predict the concentration of pollutants at the receptor point (estimated concentration point / relative concentration is accepted) located 500 meters from the highway (Benson, 1989). The predicted pollutants are relatively inert, such as carbon monoxide (CO), nitrogen dioxide (NO_2), and suspended particles. Figure 1 shows a series of elements based on the angle between the road and the wind direction.

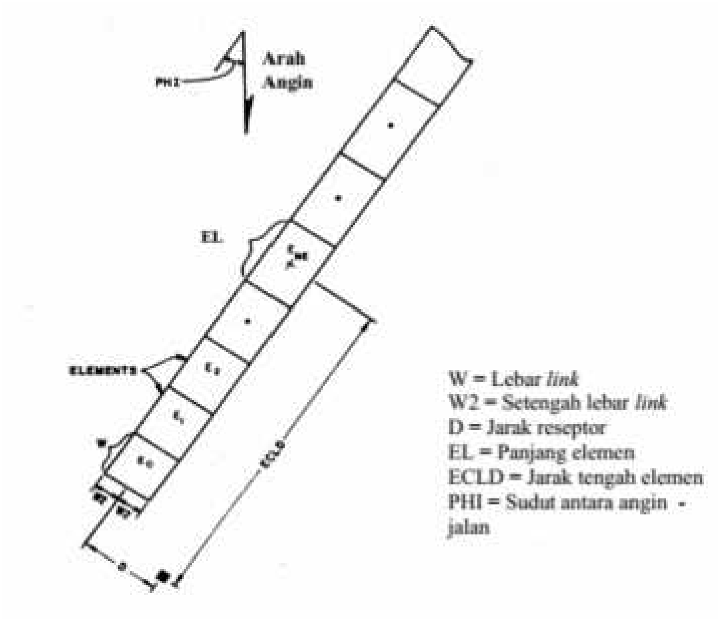

Figure 1. Element series used in CALINE-4
Source: Colls.

Each element is modeled as an equivalent Finite Line Source Source (FLS) that is positioned usually (perpendicular) to the wind direction and centered at the midpoint of the element. The x-y coordinate system can be aligned with the wind direction and centered in the center of the component. The emission levels occurring in each component are sourced from as long as the Gaussian dispersed FLS of the details. The length and orientation of FLS is a function of element size and the angle between wind - road [8].

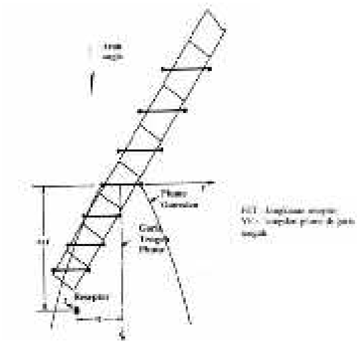

Figure 2. Element Series represented by equivalent Finite Line Source
Source: Benson [8]

To distribute emissions into a form that can be formulated then each element is divided into 3 sub-elements, namely the central sub-element and 2 additional sub-elements (ZON1, ZON2, and ZON3). The sub-element geometry is a function of the size of the details and the wind-road angle. The average emission rate assumed equal on all aspects to be computable.

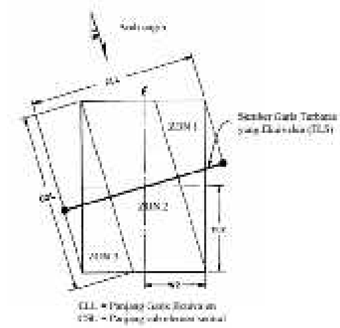

Figure 3. Representation of Finite Line Source element
Source: Benson

Emissions for additional sub-elements modeled are reduced linearly (toward zero) at the end point of FLS [8].

4. Methodology

4.1 Research Time and Location

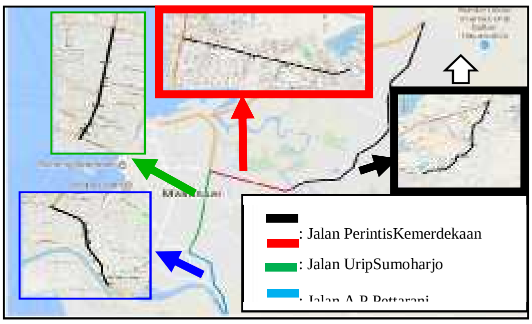

Figure 4. Research Location

The research conducted at A.P. Pettarani street on July 19, 2017, Sultan Alauddin street on September 6, 2017, and Urip Sumoharjo and Perintis Kemerdekaan street on September 10, 2017.

Table 2. Location of Receptors

No	Receptor			
	A.P. Pettarani	**Sultan Alauddin**	**UripSumoharjo**	**PerintisKemerdekaan**
1	Hotel Amaris	UIN Alauddin	Graha Pena	M'TOS
2	Pasar Tradisional	RM Wong Solo	Universitas Bosowa	SMK Yapmi
3	McD	STIE Nobel	Masjid 45	UIM
4	STMIK	McD	Menara UMI	STMIK Dipanegara
5	STIE Wira Bhakti	POLINAS	UMI	STMIK AKBA
6	Ramayana	KFC	RS Ibnu Sina	UNHAS
7	Pizza HUT	UNISMUH	Kantor Gubernur	IMMIM
8	STIA LAN	Pizza HUT	SPBU	RS UNHAS
9	Masjid H.M. Asyik	STIKPER Gunung Sari	Masjid Baiturahman	STIKES & STIPER Tamalate
10	KFC	PolsekRappocini	Masjid Nurul I'tihad	BRI Coorporation University
11	RSIA Paramouth	RM Anging Mammiri	Taman MakamPahlawan (TMP)	STIKES Nusantara
12	BKKBN	Masjid	Kodam	RS Daya
13	UNM	Makam Arung Palaka	SPN Batua	Pasar
14	Kawasan SD IKIP	Kodim	GPIB	Terminal Daya
15	Hotel Clarion	SMPN 2 Sungguminasa	Masjid Ridho Allah	Daya Grand Square
16	Telkom	-	Hotel Kammanre	Manggala Junction
17	MAN Model	-	-	SMP Katolik Sudiang
18	-	-	-	SDN PAI
19	-	-	-	SDN Mandai
20	-	-	-	Bandara

4.2 Instrument.
The hardware used is GPS map 60CSx Garmin and Anemometer San fix. While the software used in this research is WRPLOT View, Caline4, and Golden Surfer 9.

5. Data Collection

5.1 Primary Data.
Primary data used in this research are 1) Height of research location from sea level where this data obtained from the result of measurement using GPS Map 60CSx GARMIN. 2) Wind speed data is obtained from the average hourly measurements for 24 hours using the Anemometer San fix tool. 3) Air condition data obtained from analysis using Anemometer San fix tool. 4) Road coordinate and receptor data obtained from measurement using GPS Map 60CSx GARMIN. 5) Emission factor data, which is calculated by using equation (1).

5.2 Secondary Data.
Secondary data is data obtained from related agencies. The purpose of this method of data collection is to get direction data and wind speeds that have been issued by the agencies related to the scope of the study.

Secondary data used in this research are 1) Wind direction data where this data obtained through the website of Meteorology, Climatology, and Geophysics (BMKG) of Makassar City. 2) CO concentration is obtained from Langit Biru report which is a work program of the Ministry of Environment in cooperation with Regional Environment Agency South Sulawesi Province in 2016. 3) Road Width and number of vehicles obtained from Langit Biru report which is the work program of the Ministry of the Environment in collaboration with the Regional Environment Agency of South Sulawesi Province and also derived from research that was done before in 2016.

6. Data Characteristic

Characteristic of data is a summary of secondary data and primary data needed in this study. Information of data type, data source obtained, and also data function in this research aims to simplify in data grouping and data usage.

Table 3a. Data Characteristic

Data	Data Type	Data Source	Data Function
Location Height	Primary	Measurement using GPSmap 60CSx GARMIN	Used in CALINE-4 (*Job Parameters*)

Table 3b. Data Characteristic

Data	Data Type	Data Source	Data Function
Wind speed	Primary	Measurement using Anemometer Sanfix	Used in WRPLOT View dan CALINE-4 (*Run Conditions)*
Wind direction	Secondary	BMKG	Used in WRPLOT View dan CALINE-4 (*Run Conditions)*
Temperature	Primary	Measurement using Anemometer Sanfix	Used in CALINE-4 (*Job Parameters*)

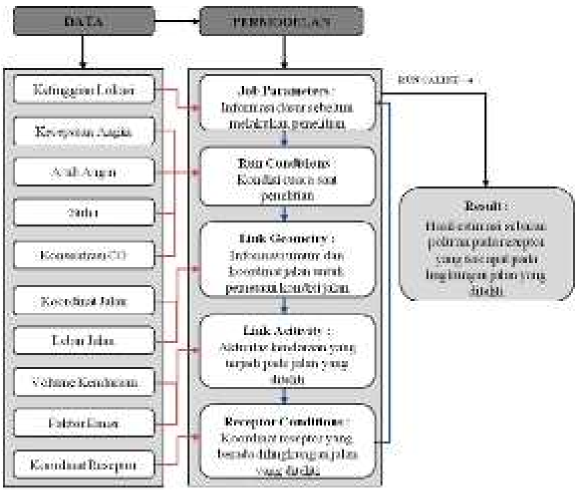

Figure 5. Flowchart CALINE-4

7. Data Analysis

Figure 6. *Flowchart* Data Analysis

8. Result and Discussion

8.1 Traffic characteristics.

8.1.1 Vehicles Volume. Volume of vehicles on A.P. Pettarani, Sultan Alauddin, UripSumoharjo, and Perintis Kemerdekaan street obtained from BLHD South Sulawesi Province at peak hour of the morning at 07:00 to 08:00, peak hour at noon at 12:00 to 13:00, and afternoon 17:00-18:00 assuming that the volume of vehicles entering on the road is equal to the volume of vehicle when out of the road, can be seen in table 4:

Table 4. Vehicles Volume

Road Name	Time	Vehicles Volume (Unit)				Total (Unit)
		MC	LV	Truk	Bus	
A.P. Pettarani	07.00 – 08.00	9.915	1.952	42	2	11.911
	12:00 – 13:00	5.126	2.405	118	11	7.660
	17:00 – 18:00	7.842	2.797	129	8	10.776
Sultan Alauddin	07.00 – 08.00	8.976	1.914	102	-	10.992
	12:00 – 13:00	7.422	1.710	66	-	9.198
	17:00 – 18:00	7.908	1.974	54	-	9.936
Urip Sumoharjo	07.00 – 08.00	6.556	1.407	35	12	8.010
	12:00 – 13:00	4.169	1.314	41	5	5.529
	17:00 – 18:00	6.917	1.233	32	2	8.184
Perintis Kemerdekaan	07.00 – 08.00	16.848	4.422	60	18	21.348
	12:00 – 13:00	9.840	2.988	258	12	13.098
	17:00 – 18:00	8.184	3.006	204	14	11.408

MC = Two wheels vehicle (Motorcycle); LV=four wheels vehicle (Car)

8.1.2 Emission Quantity. The calculation result of the emission quantity (q) for the CO parameter by using Equation (1) in the A.P. Pettarani, Sultan Alauddin, Urip Sumoharjo, and Perintis Kemerdekaan street are as follows:

Table 5. Emission quantity (q) of vehicles

Road Name	**Time**	**CO Emission Quantity / Vehicle type (g/mi)**				**Emission Quantity (g/mi)**
		MC	**LV**	**Truck**	**Bus**	
A.P. Pettarani	07.00 – 08.00	138.810	78.080	352.8	22	11,327
	12:00 – 13:00	71.764	96.200	991,2	121	13,707
	17:00 – 18:00	109.788	111.880	1.083,6	88	12,842
Sultan Alauddin	07.00 – 08.00	125.664	76.560	856.8	0	11,473
	12:00 – 13:00	103.908	68.400	554.4	0	11,671
	17:00 – 18:00	110.712	78.960	453.6	0	11,883
Urip Sumoharjo	07.00 – 08.00	91.784	56.280	294	132	11,512
	12:00 – 13:00	58.366	52.560	344.4	55	12,504
	17:00 – 18:00	96.838	49.320	268,8	22	11,113
Perintis Kemerdekaan	07.00 – 08.00	235.872	176.880	504	198	12,027
	12:00 – 13:00	137.760	119.520	2.167,2	132	12,307
	17:00 – 18:00	114.576	120.240	1.713,6	154	12,884

8.2 Dominant wind speed and direction (wind rose).

The first measurements were carried out on the road A.P. Pettarani that is on July 19, 2017, in cloudy weather conditions with a temperature of 28ºC. Measurements were carried out for 24 hours and obtained an overview of the dominant wind direction and dominant wind speed as follows:

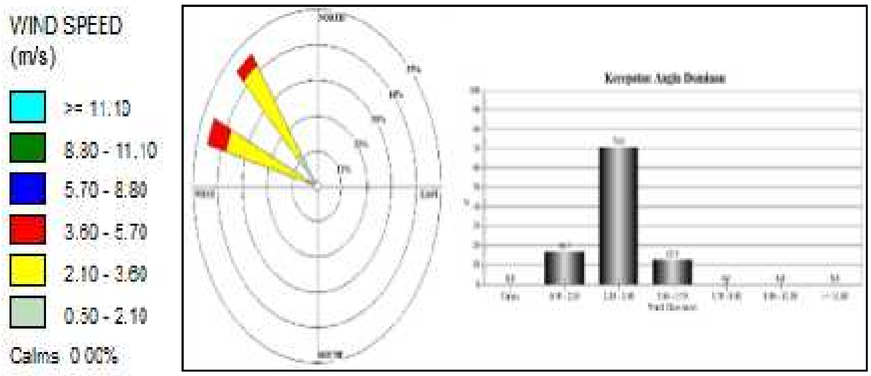

Figure 7. Dominant Wind Direction and Dominant Wind Speed A.P. Pettarani Street

Based on figure 7, it can be seen that the degree of wind direction is dominant on A.P. Pettarani on July 19, 2017, is with the wind angle blowing towards 292.5º and 315º with the dominant wind speed is in the range of 2.10 - 3.60 m/s. The prevailing wind speeds in the range of 2.10 - 3.60 m/s is 70.8%.

In the second measurement conducted on the road of Sultan Alauddin on September 6, 2017, in sunny weather conditions with a temperature of 32.7ºC. Measurements were made for 24 hours and obtained an overview of the predominant wind direction and wind velocity as follows:

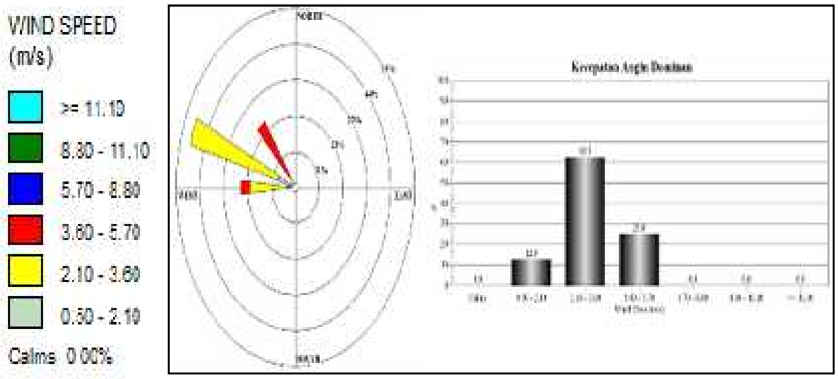

Figure 8. Dominant Wind Direction and Dominant Wind SpeedJl. Sultan Alauddin Street

Based on figure 8, it can be seen that the degree of wind direction is dominant on Sultan Alauddin on September 6, 2017, is the angle of wind blowing towards 292.5 º with the dominant wind speed is in the range of 2.10 - 3.60 m / s by 62.5%.

Then the third measurement is done at Urip Sumoharjo on September 10, 2017, in sunny conditions with air temperature is 30ºC. Measurements were carried out for 24 hours and obtained an overview of the dominant wind direction and dominant wind speed as follows:

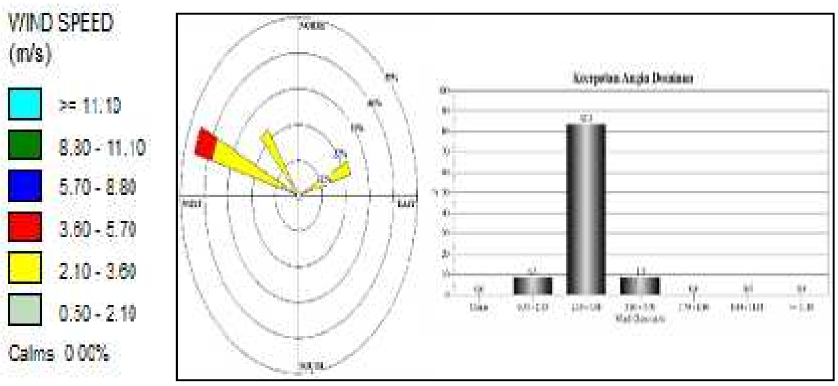

Figure 9. Dominant Wind Direction and Dominant Wind SpeedJl. UripSumoharjo

Based on figure 9, it can be seen that the degree of wind direction is dominant at Urip Sumoharjo street on September 10, 2017, is with a wind angle blowing towards 292.5 º with the dominant wind speed is in the range of 2.10 - 3.60 m / s. The dominant wind speeds in the range of 2.10 - 3.60 m/s is 83.3%.

At the last measurement conducted on the same day that is on September 10, 2017, Perintis Kemerdekaan street, the measurement is done in sunny weather conditions with the air temperature is 30ºC. Measurements were carried out for 24 hours and obtained an overview of the dominant wind direction and dominant wind speed as follows:

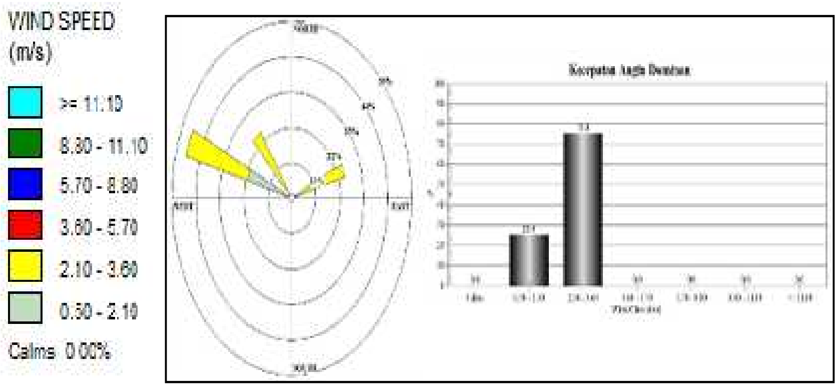

Figure10. Dominant Wind Direction and Dominant Wind SpeedJl. Perintis Kemerdekaan

Based on figure 10, it can be seen that the degree of wind direction is dominant at Perintis Kemerdekaan street on September 10, 2017, is a wind angle blowing towards 292.5º with the dominant wind speed is in the range of 2.10 - 3.60 m/s. The dominant wind speeds in the range of 2.10 - 3.60 m/s is 75%.

8.3 Estimation of traffic Emission Distribution

8.3.1 Prediction of CO A.P. Pettarani street. On the A.P. Pettarani, selected as many as 17 receptors located in the vicinity of the road environment and has the most possibility of being exposed by vehicle emissions through the road.

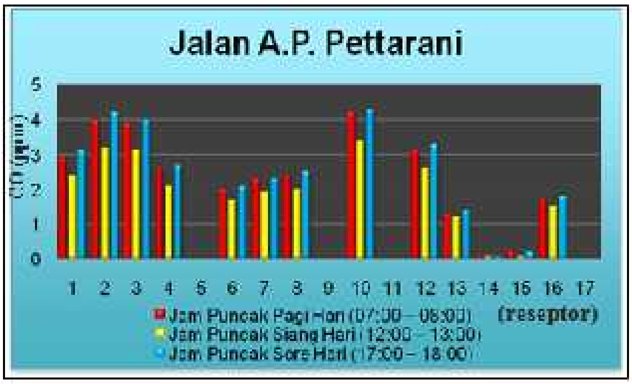

Figure 11. Pollutant Concentration Estimation CO Jl. A.P. Pettarani

Estimated results of the distribution of traffic emissions on A.P. Pettarani using CALINE-4 model shows that during the peak hour of the morning, noon, and afternoon, KFC receptor has the highest CO pollutant level that is equal to 4,2 ppm, 3,4 ppm, and 4,3 ppm. While the lowest CO pollutant level at the peak hour of the morning, noon, and afternoon that happened at receptor STIE Wira Bhakti, Mosque H.M. Fun, RSIA Paramouth, and MAN Model that is 0 ppm.

8.3.2 Prediction of CO Sultan Alauddin Street. On the road of Sultan Alauddin, selected as many as 15 receptors located in the vicinity of the road environment and has the most exposure possibilities by vehicle emissions through the road.

Figure 12. Pollutant Concentration Emission of CO Jl. Sultan Alauddin

The result of the estimation of the distribution of traffic emission on the road of Sultan Alauddin using CALINE-4 model shows that during the peak hour of the morning, noon and afternoon, Rappocini Police receptor has highest CO pollutant that is 3,8 ppm, 3,2 ppm, and 3.5 ppm. While the lowest CO pollutant level at the peak hour of the morning, noon, and afternoon that is at receptors UIN Alauddin, POLINAS, Pizza HUT, RM Anging Mammiri, and Kodim that is 0 ppm.

8.3.3 Prediction of CO Urip Sumoharjo street. On the Urip Sumoharjo road segment, 16 receptors are selected around the road and are most likely to be exposed to vehicle emissions through the road.

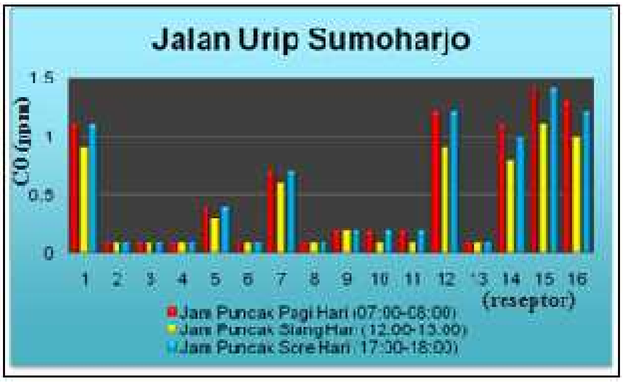

Figure 13. Pollutant Concentration Estimation of CO Jl. Urip Sumoharjo

The result of the estimation of the distribution of traffic emission on Urip Sumoharjo Makassar road using CALINE-4 model shows that at the peak hour of the morning, noon, and afternoon, Ridha Allah receptors have the highest CO pollutant value of 1.4 ppm, 1.1 ppm, and 1.4 ppm. While the lowest CO pollutant level is at receptor of Bosowa University, Mosque 45, UMI Tower, Ibnu Sina Hospital, SPBU, and SPN Batua that is 0,1 ppm in morning and afternoon peak, plus Nurul Ijtihad Mosque receptor and Hero Cemetery Park at peak hour during the noon that is equal to 0.1 ppm.

8.3.4 Prediction of CO Perintis Kemerdekaan Street. On the Perintis Kemerdekaan road segment, 20 selected receptors are located in the vicinity of the road and are most likely to be exposed to vehicle emissions through the road.

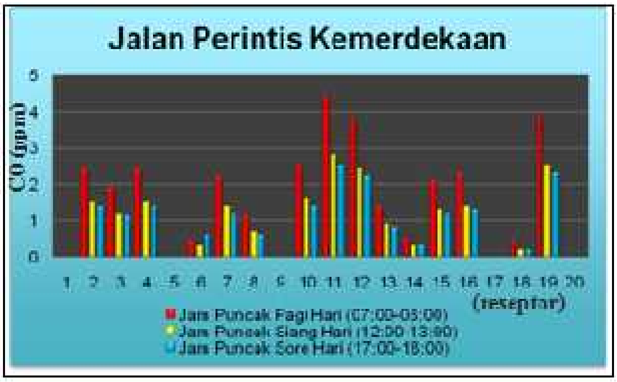

Figure 14. Pollutant Concentration Estimation of CO Jl. Urip Sumoharjo

The result of estimation of the distribution of traffic emission on Perintis Kemerdekaan street using CALINE-4 model shows that at the peak hour of the morning, noon and afternoon, STIKES Nusantara receptors with highest CO pollutant value of 4.4 ppm, 2.8 ppm, and 2.5 ppm. While CO pollutant level with the lowest value at the peak hour of the morning, noon, and afternoon that happened at receptors M'TOS, STMIK Akba, STIKES & STIPER Tamalate, Junior Highschool Catholic Sudiang, and Airport that is equal to 0 ppm.

9. Conclusion

Based on the purpose of this study which is based on the results of research and data analysis, then obtained the following conclusions: The highest impact of CO pollutants generated by traffic on A.P.Pettarani found in the KFC receptor that is with the prediction of CO pollution of 4.3 ppm that occurs in the condition of the peak hour of the afternoon is 17:00 - 18:00. While in Sultan Alauddin occurred at Rappocini Police receptor of 3.8 ppm at peak hour of the morning, UripSumoharjo road occurred at Ridha Allah Mosque receptors of 1.4 ppm at peak morning conditions, and Independence Pioneer road occurred at receptors STIKES Nusantara which is a receptor with the predicted impact of CO pollutant pollution is the largest of 4.4 ppm which occurs in the peak hour condition of the morning that is at 07:00 to 08:00.

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