International Journal of GEOMATE, Dec., 2018 Vol.15, Issue 52, pp.214-221
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.52.92919
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

ANALYSIS OF CO EMISSION OF HETEROGENEOUS TRAFFIC USING CALINE 4 AT DAYA PASSENGER TERMINAL IN MAKASSAR INDONESIA

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*Corresponding Author, Received: 10 Jul. 2018, Revised: 02 Aug. 2018, Accepted: 20 Sept. 2018

ABSTRACT: Motor vehicles have been a primary source of CO emissions in many major cities in the world, including in Makassar, Indonesia. The increasing of the motor vehicle under heterogeneous traffic condition on the Daya Passenger Terminal (DPT) leads to the air pollution rise that emitted by the vehicles as consequently. This study aims to predict the quantity and model of CO emissions distribution using the Caline 4 in DPT. In 2016, vehicle volume and CO emission data collection were conducted on 10 receptors in DPT and meteorological data obtained from Indonesia Agency in the Makassar region. The results are the emissions tend to be the same in 2016 and 2017 with the largest amount of CO emissions in receptor 9 and compared to 2018 decrease by 33%. The CO emission distribution model is highly influenced by wind speed and dominant direction and has different models, which are 5, 3, 4 in 2016, 2017, and 2018 respectively. For further research, this study is particularly useful as preliminary information related to air quality mitigation.

Keywords: CO emissions, terminal, Caline 4, heterogeneous traffic, Makassar

1. INTRODUCTION

Emission of gasses and particle came from transportation activity going up into the atmosphere might cause problems such as reducing the quality of the environment. Generally, the negative impact of the environment increases when vehicle number increases. Amount of emissions proportional to the number of vehicles, it could threaten human health, especially in the lungs [1].

One of the transportation activities occurred in the passenger terminal area. The high level of mobilization and necessity of easy, cheap and safe transportation will also encourage the higher demand for land transportation [2]. Another impact of various modes of transportation is air pollution around roads in the terminal area with various emissions that originating from motor vehicles especially carbon monoxide (CO) gases [3-5]. This terminal area is needed to be maintained as a comfort zone including clean air. Air quality is not only influenced by atmospheric conditions but also controlled by meteorology parameters, especially the temperature profile close to the ground surface [6].

The level of CO background, wind speed, and wind direction at the existing site [7-8] influenced the prediction of CO concentration. To protect the nearby population, environmental regulators must firstly quantify the size of the impact area affected by the use of roads and then preventive identity and mitigating countermeasures [9].

Daya Passenger Terminal (DPT), a bus station is located in Perintis Kemerdekaan Street, km.15, Makassar City, with an area of 12 Ha. DPT serves 34 routes, 19 transport routes within Province (AKDP), 12 routes of Inter Provincial (AKAP), and 3 routes within Makassar city (ANGKOT) [10,11]. Mostly large buses are used for AKDP and AKAP, this kind of vehicles can carry about 47-50 passengers, while small busses are used for Angkot which has a maximum capacity of 11 passengers. In addition, passengers have other options to take, light vehicle (LV) and motorcycles (MC). These vehicles can take passengers to their destination. Based on several types of modes, it can be concluded that traffic in DPT area is heterogeneous [5].

Gas of CO is colorless, odorless, and tasteless. CO is produced from incomplete combustion of carbon compounds and lack of oxygen. This gas is one of the most widely distributed emissions in the air. According to the Environmental Agency of South Sulawesi (BLHD) in 2014 [12], CO emissions from motor vehicles increased 500% from 10.8 ug/m3 in 2012 to 65 ug/m3 in 2013.

The Caline 4 model [13] has been used widely to predict air quality in highways under homogeneous traffic based on local meteorological state [14]. This model requires relatively lesser skills and input data than other vehicle dispersion models. Several previous comprehensive studies have been conducted on the validation and evaluation of Caline 4 model on heterogeneous traffic conditions) [7]. Caline 4 model is a simple line source Gaussian plume dispersion model which predicts the concentrations of CO [8].

Based on some data earlier and high potential of

CO emissions from heterogeneous traffic in the road segment of DPT and impact of CO pollutants on health, this research was conducted to analyze 1) CO emission of heterogeneous traffic based on Caline 4 and 2) Distribution pattern of CO emission on road segment at Daya Passenger terminal in Makassar city.

2. MATERIAL AND METHODS

2.1 Characteristics of Vehicle

Characteristics of the vehicle consist of Vehicle type and emission factors. Measurement of vehicles number was done by classifying vehicle-based on the light vehicle (LV), heavy vehicle (HV), and motorcycle (MC) [15]. The purpose of grouping vehicle is to calculate traffic volume based on vehicle unit and quantity of emissions easily.

The emission factor of each vehicle group refers to the State Minister of Environment of Indonesian Republic No.12/2010 [16], the emission factor for CO, as listed in Table 1.

Table 1 CO emission factor

Emission factor (g/km)	Motor cycle	Light vehicle	Heavy vehicle	
	MC	LV	Truck	BUS
CO	14,0	32,4	11,0	8,4

2.2 Study Location and Survey of Primary Data

2.2.1 Location of study

This research was located on the street around Daya Passenger Terminal (DPT) in Makassar city, as shown in Figure 1.

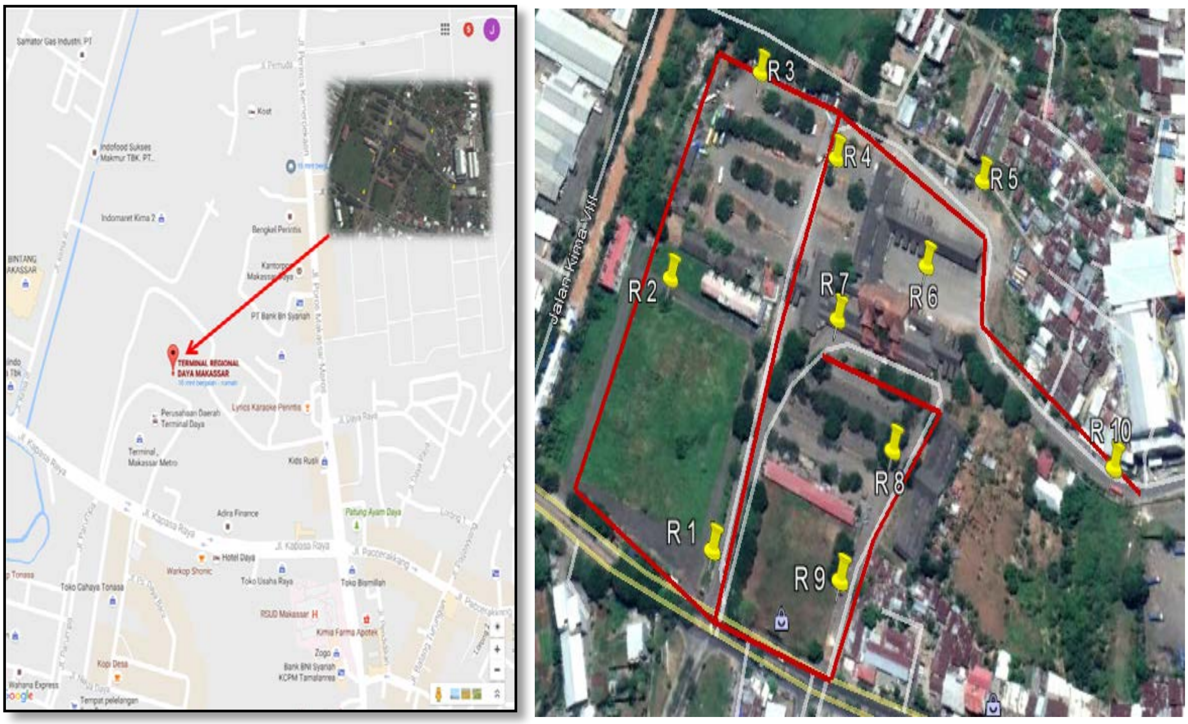

Fig.1 Study and receptor location on the DPT map.

The traffic measurement and monitoring of CO emissions were conducted on several road segments in DPT area. The area was divided into 10 segments of the road, there is a receptor in each segment. This study also refers to SNI No. 19-7119.6-2005 of Determination of Test Sampling [17]. Segment location of the roads and coordinates of 10 receptors are shown in Table 2.

2.2.2 Primary data

Primary data in this study included coordinates of study points, meteorological data, and vehicle volume. The data which were analyzed in 2016 was used to observe the trend of CO distribution in 2017 and 2018. Primary data, locations, time, survey and equipment are listed in Table 3.

Micro-meteorological parameters such as wind speed and temperature are measured directly on the survey location. Data of dominant wind direction, from Indonesia Agency for Meteorology, Climatology, and Geophysics (BMKG), Makassar, Indonesia [18], stability class and mixing height based on Caline 4.

Table 2 Location of road segments and coordinate of 10 receptors

Road segments	Receptors	Location	Coordinate
1	R1	Terminal entrance gate	05^{0}06’42.3” & 119^{0}30’23.5”
2	R2	Field	05^{0}06’36.6” & 119^{0}30’21.9”
3	R3	Car Parking AKAP and AKDP	05^{0}06’31.8” & 119^{0}30’24.7”
4	R4	Workshop and car washing place	05^{0}06’34.0” & 119^{0}30’27.2”
5	R5	Place of bus departure	05^{o}06’34.7” & 119^{o}30’31.9”
6	R6	In front of the waiting room	05^{o}06’36.6” & 119^{o}30’30.0”
7	R7	Front gate of retribution	05^{o}06’37.7” & 119^{o}30’27.2”
8	R8	Car parking	05^{0}06’40.5” & 119^{0}30’28.8”
9	R9	Public transport routes and private vehicles	05^{0}06’43.0” & 119^{0}30’27.2”
10	R10	Exit terminal gate	05^{o}06’41.1” & 119^{o}30’35.3”

Table 3 Survey of primary data, location, time of survey and equipment

No	Primary Data	Location	Time	Equipment
1	Coordinate of receptor	Road segment	06.00 AM-20.00 PM	GPS map 60CSx Garmin
2	Traffic Data	in		Handy cam, tripod, and form of data
3	Wind speed	terminal		Anemometer Sanfix

Data for wind rose is drawn using WRPLOT software and pattern of CO emission distribution using Golden Sufer 9 software. All of the data is calculated by Office Excel.

2.2.3 Description of Caline 4 model

Caline 4 model is the fourth-generation simple source of the Gaussian dispersion model [13].

Based on that description, one of the aims of this study is to predict the quantity of CO emissions. Then, Input parameters and variable measured for Caline 4 summarized in Table 4.

Table 4 Input parameter of Caline 4 model

Parameter	Measured variable	Measurement method	Unit
Traffic Data	o Motorcycle (MC) o Light vehicles (LV) o Heavy vehicles (Truck and BUS)	on-site video camera	Vehicle unit
Characteristics of the road in Daya Passenger Terminal	o Mixing zone width (road wide + 3 m on both side of the road) o Road type o Road Alignment	measured physical observation *Google map*	meter At-grade Straight
CO Emission	o The factor of CO Emission o Background of CO concentration	*Refer to* [16] *0.10* [19]	g/mil ppm
Receptor	o Coordinate 10 point o 10 points (R1-R10)	*compass* *Primary data*	Degree Celsius -
Meteorology	o Wind speed o Wind direction o Temperature o Mixing height o Stability class	*Primary data* *Primary data* *Refer to* [18] *600* *Refer to* [13]	m/second Degree meter 7

Emission quantity for each vehicle type was calculated using Eq. (1) [4].

$$E=\sum_{i=1}^{n} EFt \text{ x } Vt, i \quad (1)$$

Where: E = emission of motor vehicle; EF = emission factor; V = volume of vehicle; t = vehicle type; i = vehicle i; n = vehicle n.

3. RESULTS AND DISCUSSION

3.1 Volume of Vehicle

Based on a survey it was found that dominant vehicle volume (up to 100%) is the heavy vehicle, which occurred between 09:00-14:00 and 18:00-

20:00 at R4. The second and third largest vehicle volume were motorcycles (80.09%) between 17:00-18:00 at R10 and light vehicle (80.00%) between 15:00-16:00 at R4, respectively. Accordingly, it can be seen that the dominant vehicle volume occurred at R4. Percentage of vehicle volume at each point of observation for the light vehicle (LV), heavy vehicle (HV), and motorcycle (MC) are plotted in Fig. 2.

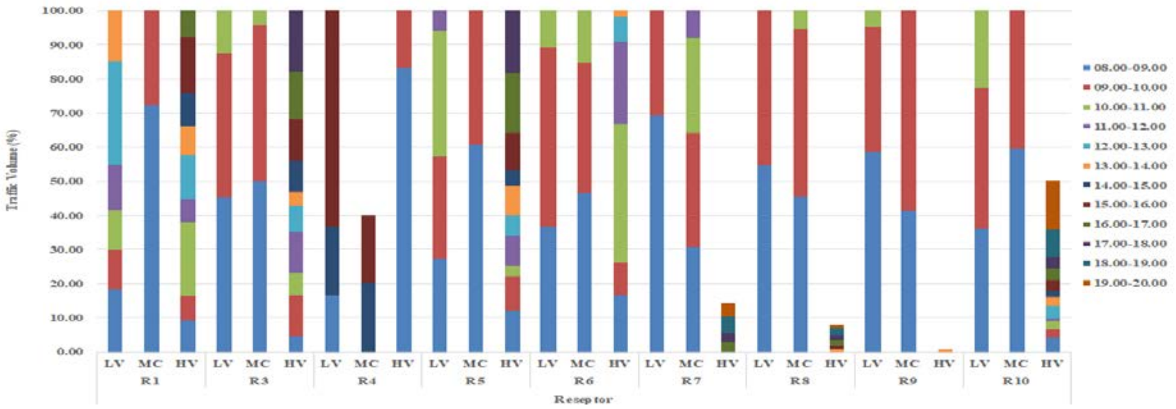

Fig. 2 Percentage of vehicle volume at each receptor

3.2 Meteorology

The dominant wind was 315 degrees to the Northwest with a standard deviation of 27.88 in 2016 and 2017, while in 2018 dominant wind was 270 degrees to the Northwest with a standard deviation value of 50.57.

Speed and direction of wind were illustrated by Windrose and plotted using WRPLOT. Figure 3 described speed and direction of wind for October-November 2016 and 2017, and March-April 2018. Stability class was 7, wind speeds were various and mostly less than from 3.50 m/s with 600 m mixing height.

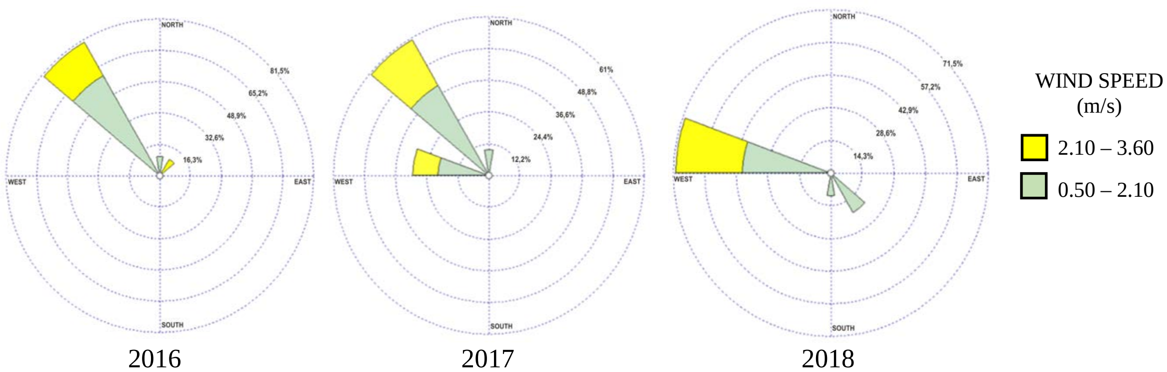

Fig. 3 Windrose in study location with an average wind speed of 0.50-3.60 m/s.

3.3 Prediction of CO Emission Quantity

The quantity of CO emission for all receptor was determined after all data entered into Caline 4, as shown in Figure 4−6.

The largest concentration of CO emissions occurs in R9 starting from 17:00 PM to 8:00 PM that is 0.3 ppm in 2016 and 2017, as it has been observed in other analyzes that CO concentration was 3 ppm achieved with low wind speeds (<3 m/s) [20] and winds parallel to the highway. While the quantity of CO emissions attained 0.2 ppm smaller in 2018 although the volume of vehicles increased an average of 7% per year [21]. Meteorological parameters, wind velocity, and wind direction are most influence CO concentration. Wind speed was found to be inversely proportional to the predicted CO concentration.

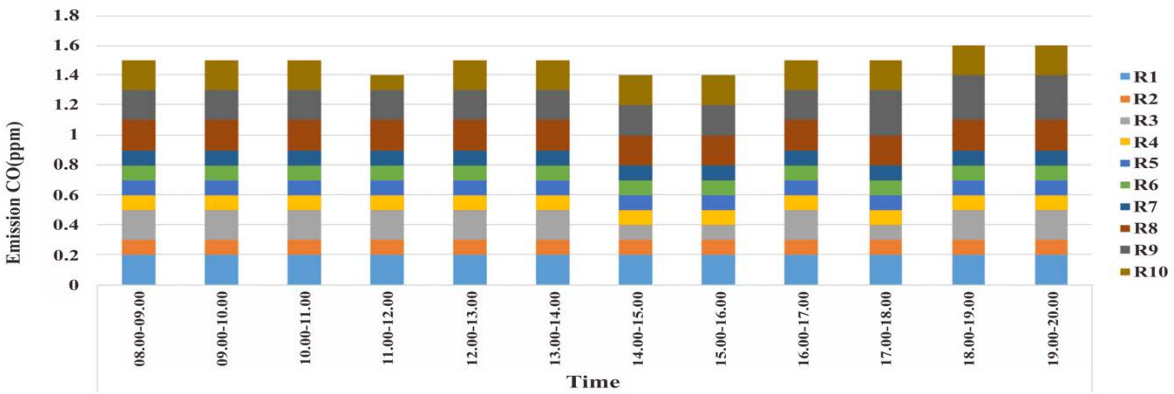

Fig. 4 Quantity of CO emission in 2016

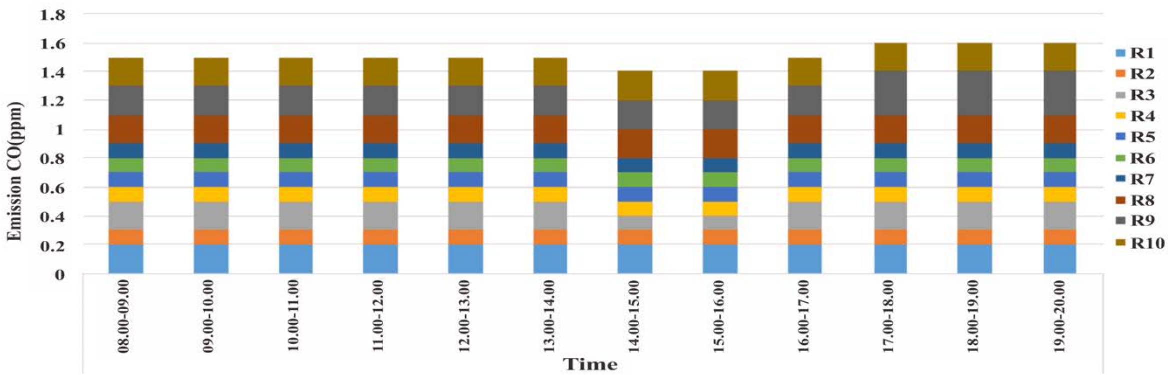

Fig. 5 Quantity of CO emission in 2017

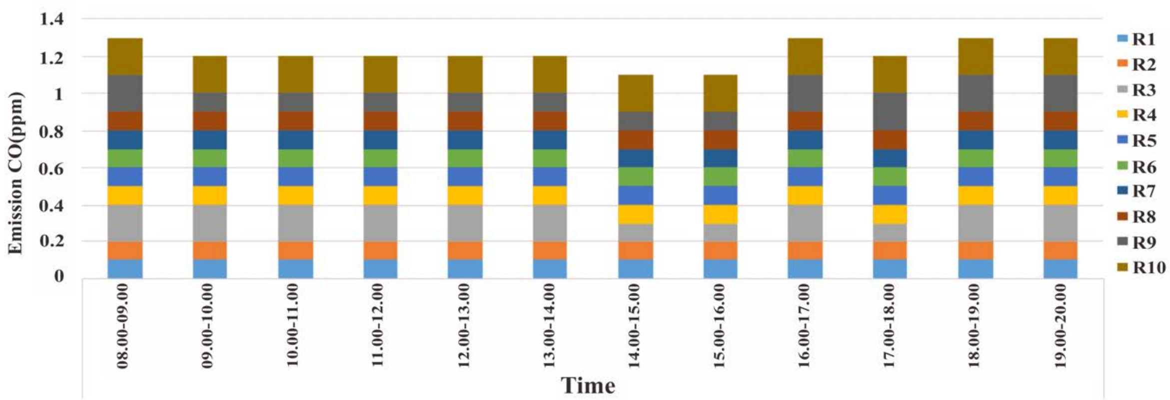

Fig. 6 Quantity of CO emission in 2018

In fact, the increase in wind speed will produce a decrease in CO concentrations of 30% and 100% respectively [7]. Furthermore, the Caline 4 predicts CO emissions as no contribution from traffic when the location of the was a perpendicular receptor of the highway [20], as in R2, R4, R5, R6, and R7 were receptors located perpendicular to the wind. The quantity of CO emission is 0.10 ppm at those receptors during the observation time from 08:00 to 20:00 in 2016, 2017, and 2018.

3.4 Distribution of CO Emission

The distribution of CO emissions due to heterogeneous traffic in the DPT and its impact magnitude can be seen in Figure 7-9. There are 5 distribution models of CO emission in 2016 (Fig.7), the highest average of CO emission quantity was illustrated in the orange scale that is at receptors of R1, R3, R8, R9, and R10 from 08:00 until 11:00. The R9 receptor was exposed to CO emissions from 08:00 to 20:00.

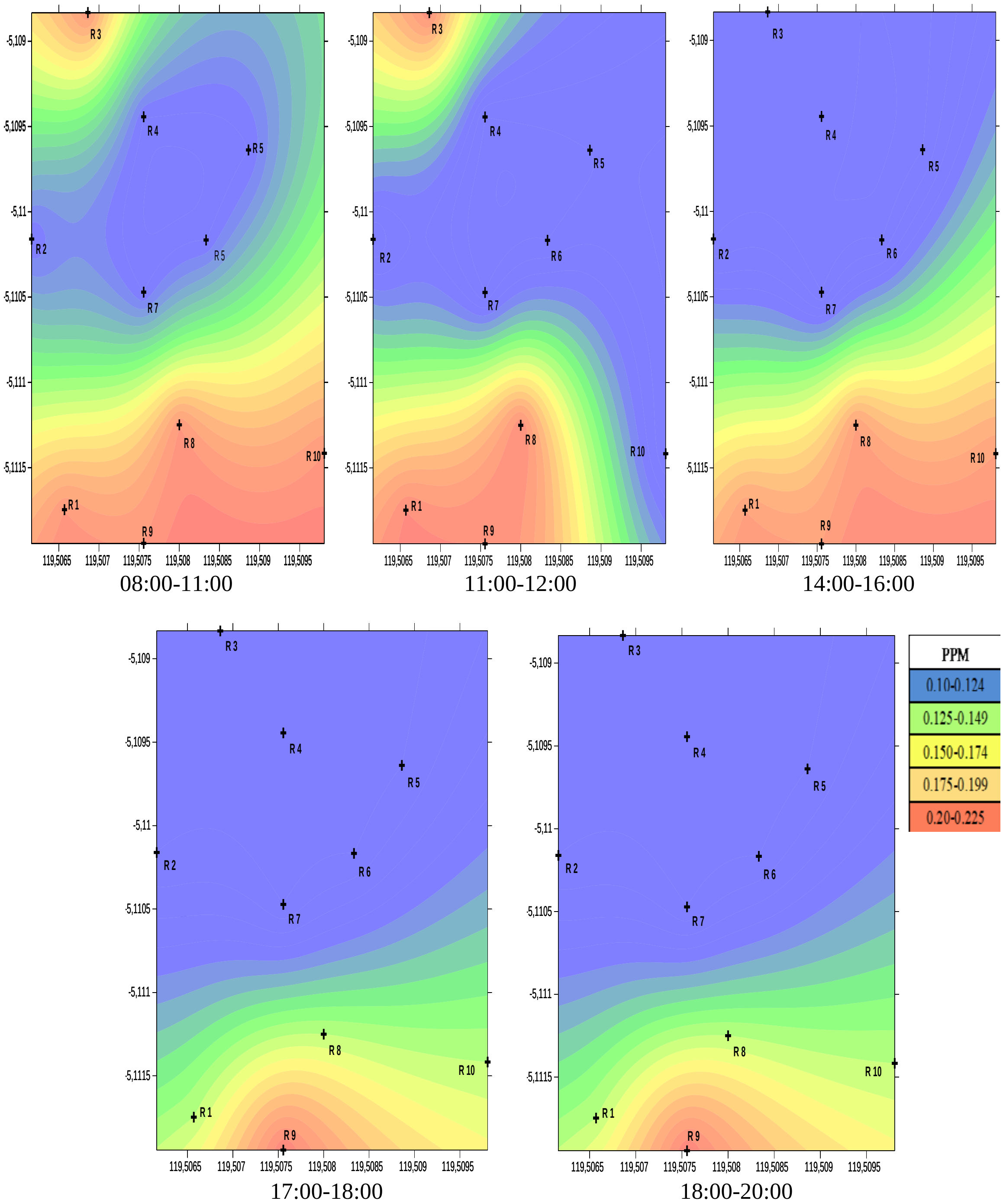

Fig. 7 Distribution pattern of CO emission in 2016

In 2017, there are three models of distribution pattern (Fig. 8), each pattern has a different session of observation, which is 08:00-14:00, 14:00-16:00, and 17:00-20:00. The distribution pattern of CO emission for sessions 16:00-17:00 was similar to the one at 08:00-09:00. Orange scale represented the highest quantity of average CO emission. Unlike in 2017, there are 4 distribution models of CO emission in 2018 (Fig.9). Observation time was divided into four sessions that is 08:00-09:00, 09:00-14:00, 14:00-16:00, and 17:00-18:00. The highest average CO emission quantity which was orange scale occurred at receptors of R3, R9, and R10. As for the others receptor, R1, R2, R4, R5, R6, and R7, all of them reached the purple scale at 08:00 to 20:00. The result of the CO distribution analysis is for preliminary information for air pollution mitigation including for heavy vehicle (HV) rejuvenation with higher technology were HV operating reaches 100% at R4. Hence, the amount of CO will decrease [22].

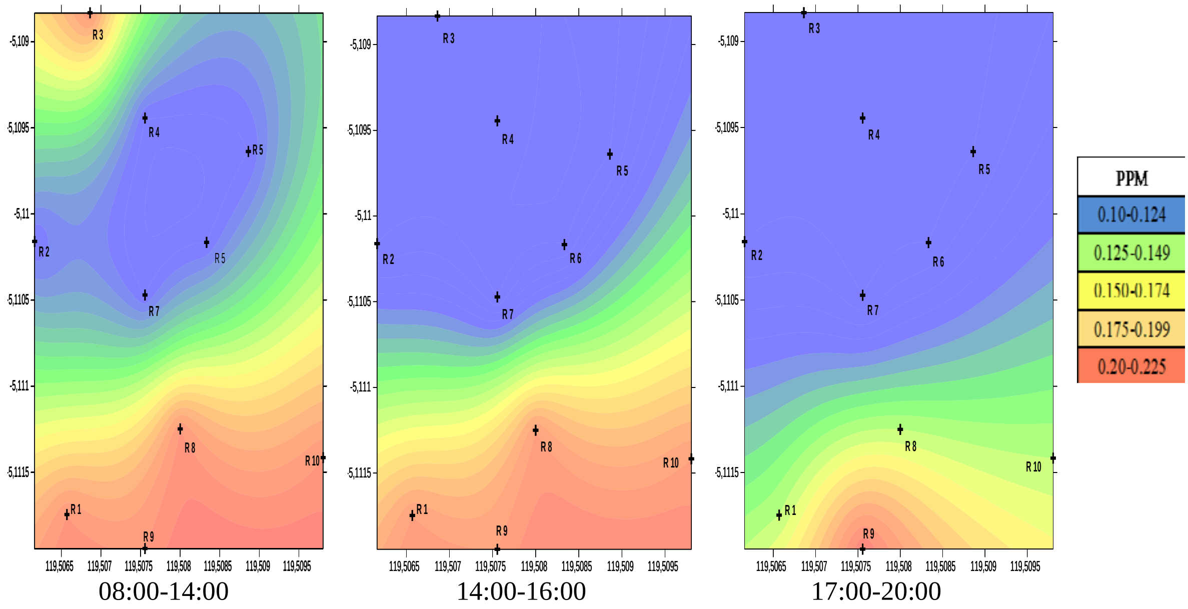

Fig. 8 Distribution pattern of CO emission in 2017

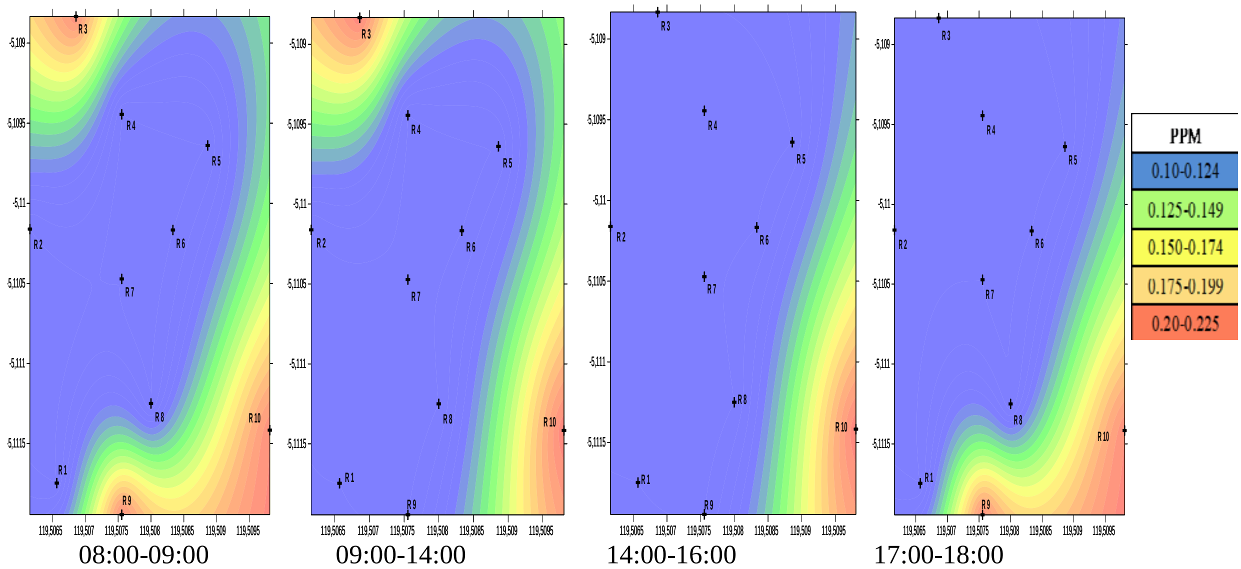

Fig. 9 Distribution pattern of CO emission in 2018

4. CONCLUSION

Concentration and distribution pattern of CO emissions for heterogeneous traffic has been predicted based on Caline 4 model. Vehicle volume, speed, and direction of the wind mixing height, and stability class at 10 receptors at DOT in Makassar City were used as input data.

Both 2016 and 2017, the dominant wind was 315 degrees toward to Northwest direction with a standard deviation of 27.881. For 2018, the major wind was 270 degrees toward Northwest direction with a standard deviation of 50.567. The volume of the dominant vehicle in several road segments around DPT were heavy vehicles (HV), motorcycles (MC), and light vehicles (LV).

The highest CO emission was 0.3 ppm observed from the receptor of R9 at 17:00-20:00 in 2016 and 2017. The quantity of CO emissions declined 33.30 % in 2018 than a previous year whereas the volume of vehicle was increased. It found that there were 5, 3 and 4 models of the distribution pattern of CO emission in 2016, 2017 and 2018 respectively. The highest average CO emission quantity indicated entering orange scale.

Ultimately, it can be concluded that increasing quantity of CO emission was influenced by vehicle volume while distribution pattern was determined by wind speed and direction.

5. ACKNOWLEDGMENTS

The author would like to acknowledge Jepi ST. and TP. Mahas Khamdalasari for survey and processing the data.

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