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Investigation of carbon monoxide (CO) concentrations on roads in the city of Makassar

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Abstract. Air pollution has long been and is still a problem for humans and the environment, a priority in countries with high vehicle rates. The contribution of gas released reaches 60-70%. Motor vehicles produce one of the pollutants, namely Carbon Monoxide (CO) gas. This research was conducted to determine the level of CO concentration results from sampling using impinger and prediction models using Caline4 software. The results of the concentration between direct measurements with the Caline4 model were then compared. This research was conducted in three streets for three working days namely Jl.Urip Sumoharjo, Jl.Talasalapang, and Jl.Nusantara. The methodology used is direct measurement using impinger, calculating vehicle volume at each measurement point, and analyzing CO concentrations using Caline4. The results of sampling showed the highest CO concentration on Jl.Urip Sumoharjo at 5.80 ppm, Jl.Talasalapang at 1.06 ppm, and Jl.Nusantara 1.15 ppm. The highest estimation results of CO concentrations with Caline4 on Jl.Urip Sumoharjo were 5.7 ppm, Jl.Talasalapang by 1.1 ppm, and Jl. Nusantara was 1.4 ppm. High or low CO concentration value depends on vehicles volume, for instance, CO concentration increases with increasing vehicles volume. In addition, it is also depends on the meteorological factor, such as, the faster the wind increases, the faster the pollutants will increase. Then compare the results of CO impinger concentration and Caline4 using the t-Test to see the difference of the two CO concentrations. Comparisons were made using the t-Test to meet the $t\text{-stat} < t\text{-critical}$ concluded that there was no significant difference between the two CO concentrations.

1. Introduction

Carbon monoxide (CO) gas is a colorless, tasteless, non-irritating, and odorless gas. This gas is produced through combustion of gas, motor vehicle fuel, petrol and solid or wood fuel, and the main danger from CO gas is interference with the blood. CO gas does not irritate but CO gas is very dangerous to be called a "silent killer". The limit on CO gas exposure allowed by OSHA (Occupational Safety and Health Administration) is 35 ppm for 8 hours/work days [1]. Levels that are considered directly dangerous to life and health are 1,500 ppm or 0.15% [2].

The CO concentration can be found by direct measurement using impinger or using software. One of software to see the prediction of CO pollutants at a point is the Caline4 software [3]. Caline4 is a program to model air emission dispersions from line sources developed by the California Department of Transportation (Caltrans). This program estimates the distribution of pollutants that are close to the highway by entering several parameters such as traffic volume per link, vehicle emission factors, meteorology, and location geometry [4].



Background CO concentration is the CO concentration in ambient air at a certain temperature with certain conditions in areas that have not been affected by pollutants from motor vehicles. The background concentration of CO has an average concentration of 0.1 ppm [5]. In Indonesia, in using Caline4, the concentration of background used ranges from 0.5 ppm - 1.5 ppm [6].

Based on some of these backgrounds, the authors conducted a study to analyze the level of CO concentration in several roads in Makassar using Caline4 and direct measurements in the field. The value of CO concentration concentration (0.1 ppm to 2.0 ppm) used in Caline4 will produce a value of CO concentration in ambient air. This value will be compared with the level of concentration obtained by direct measurement. Thus, the extent of the accuracy of the caline4 model in determining the concentration of CO in ambient air will be known.

2. Methodology

2.1. Research Time and Location

This research was conducted for three days

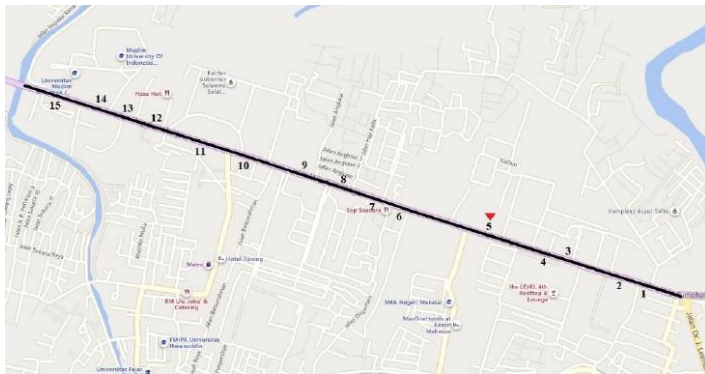
- Data collection on Jalan Urip Sumoharjo on May 21 - May 23, 2019 for 1 hour at 07.00 - 08.00 WITA.
- Data collection on Talasalapang road on 18 June - 20 June 2019 for 1 hour at 07.00 - 08.00 WITA.
- Data collection on Nusantara Road on June 25 - June 27, 2019 for 1 hour at 07.00 - 08.00 WITA.

This research was conducted on 3 road sections having different types of roads in Makassar City where each location consist of 1 measurement location point on Talasalapang Street, Nusantara Street, and Urip Sumoharjo street. The test sampling locations were determined according to SNI 19-7119.6-2005 Determination of Ambien Air Quality Monitoring Sampling Locations ie ambient air quality monitoring points by considering meteorological factors (wind direction and speed), geographic factors such as topography, and land use. The SNI explains the criteria for the location of the test sample including areas with high concentrations, namely locations that are considered to produce a lot of CO due to passing vehicle activities and areas with high population density, as well as considering the presence of vegetation in the road environment. Then from the road section which the study located, each link was selected based on the geometric changes in the road. The purpose of selecting this link was to map Caline4 software. The point of measurement locations are shown in Figure 1 below.



(a) Talasalapang

(b) Nusantara



(c) Urip Sumiharjo

- : Research Roads
- : Impinger Point
- 1,2,...,n : Receptor Point

Figure 1. Point of measurement locations.

The receptor point is the point that accepts the prediction of the concentration value on the Caline4 model in the form of coordinates. The criteria for determining receptors are carried out by looking at the dominant wind direction at the time of the study, then the selected receptors are determined where the receptors selected here are impact receivers or in sensitive areas around the road environment and are most likely to be exposed to vehicle emissions through the road. In addition, the selected receptor is 500 meters maximum from the location or source or the road which is the source of the receptor. Receptor points on different types of roads in Makassar City, can be seen in Table 1 below.

Table 1. Receptor point.

Reseptor	Nusantara	Urip Sumiharjo
Talasalapang	Temas Line	Indomaret
Pasar Tradisional	Terminal Peti Kemas	DFSK
Warkop Bundu	Titik Impinger	Kolam Renang Tirta
R8mart	Indomaret	SPN Batua Polda Sulsel
Yayasan Anak Bangsa	Coto Nusantara	Titik Impinger
De Jaz Coffee	Red Doorz	Bank BRI
Alfamart	Mabua Café	Masjid Nurul Ittihad
MAN 1 Makassar	PT Panaikang Intim	SDN Panaikang I dan II
Titik Impinger	Hotel Makassar Mulia	Indomaret
Bank BRI	Yamaha	SPBU Racing
R2 Stasionery	Diva Karaoke	Kantor Gubernur
Alfamidi	-	Nipah
Om Chick Lesehan	-	Coffe Lovers
Indomaret	-	UMI
Universitas Muhammadiyah	-	UNIBOS
Fotocopy Basamalah	-	

2.2. Data collection methods

Data collection methods used in this study are divided into 2 types of data, namely primary data and secondary data. Primary data is data obtained from direct measurements. A preliminary survey was conducted before collecting primary data to find out supporting data before making measurements. As

for the visual description of data collection in the field is shown in Figure 2. For caline4, the volume of vehicles is obtained then converted to the amount of emissions value in accordance with equation 1 below.

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

Where:

q = Emission Amount (gram/km)

EF = Vehicle Emission Factor (gram/km)

V = Vehicle Volume (vehicles/hour)

I = Type / Type of Vehicle

T = Total Vehicles

For the amount of emissions value, if the unit value is in grams/km, it can be converted to grams/miles. With the provisions of 1 gram/km = 0.621 gram/mile [7].

Secondary data is supporting data to meet the needs of the data in measurement. Secondary data used in this study are data on wind speed, wind direction, pressure, and temperature obtained from the Accuweather and National Oceanic Atmospheric And Administration (NOAA) websites.

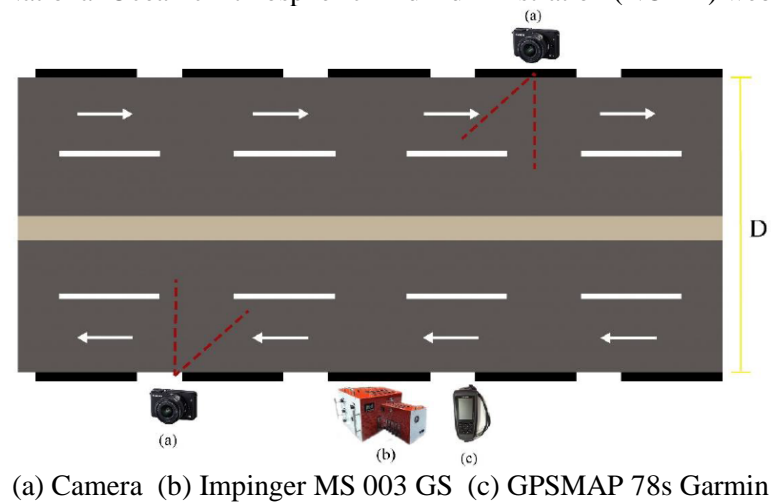


Figure 2. Measurement method

2.3. Data Processing and Analysis Methods

The data collected in the study will then be analyzed based on the objectives and models that are the main target in this study. The first stage, in analyzing data is using WRPLOT View software, where in this software we input the data of day, month, year, and hour of data retrieval, as well as data speed and angina direction [8]. The purpose of data analysis with WRPLOT View, is to determine the condition of wind rose or wind direction. and dominant wind speed. After that, the next stage is processing data using Caline4 modeling to obtain estimates of the amount of CO pollutants in the receptors in the road environment studied with variations in the background concentration of CO 0.1 ppm to 2.0 ppm, where the input file in the use of Caline4 consists of 5 (five) input types, namely Job Parameters, Run Conditions, Link Geometry, Link Activity, Receptor Position, and 1 output that is the result. The results of CO concentrations are then compared with variations in CO background concentrations to obtain the appropriate CO background concentrations [9]. Then, predict the concentration of CO using the background concentration of CO that has been obtained and estimate the distribution of CO pollutants. After getting the results of CO concentration based on Caline4 and direct measurements using impinger, a comparison test was performed to determine the difference between the concentration of the measurements with the concentration using Caline4 [8].

3. Results and discussion

3.1. Vehicle Volume

The results of the vehicle volume contained during the three days of measurement on each of the Urip Sumoharjo Road, Talasalapang Road, and Nusantara Road can then be calculated the value of the amount of emission of each vehicle volume that occurs on each of the research location roads, where the calculation of the value of the emission amount (q) in g/mile for the carbon monoxide (CO) parameter using equation (1). The value of the vehicle volume and the value of the amount of emissions on each road in the study time span can be seen in the following Table 2.

Table 2. Vehicle volume and emissions.

No.	Road	Day	Time	CO emission / vehicle type (g/mil)					Amount of Emissions (g/mil)
				MC	LV (fuel)	LV (Solar)	Truck	Bus	
1	Urip Sumoharjo	Tuesday	07am	12,324	3,021	1,118	124	0	11.11
2		Wednesday	–	13,048	2,962	1,095	89	5	10.98
3		Thursday	08am	11,055	2,823	1,044	104	7	11.18
4	Talasalapang	Tuesday	07am	2,713	478	177	6	0	10.59
5		Wednesday	–	2,695	476	176	5	0	10.59
6		Thursday	08am	2,813	558	207	4	0	10.78
7	Nusantara	Tuesday	07am	2,247	1,137	421	16	4	12.66
8		Wednesday	–	2,084	1,038	384	12	10	12.62
9		Thursday	08am	2,364	1,141	422	20	5	12.54

Table 2 shows the calculation of the emissions amount from the vehicles volume in which the average volume of vehicles multiplied by vehicle emission factors based on the type of vehicle then divided by the total volume of vehicles during 1 hour of measurement. Based on these results it can be seen that the value of the amount of emissions depends on vehicles volume of each motorized vehicle type, because the vehicles volume of the each type affects emissions amount based on the value of the emission factors for each motorized vehicle type. The value of CO emission factors from passenger cars is greater than motorcycles. This is due to the amount of emissions from passenger cars to be greater than motorbikes. The value of CO emission factors for passenger cars is greater than for motorcycles because of the vehicle engine capacity.

3.2. CO concentration from direct measurements

Direct measurement using Impinger. The measurement results for each road can be seen in the following table.

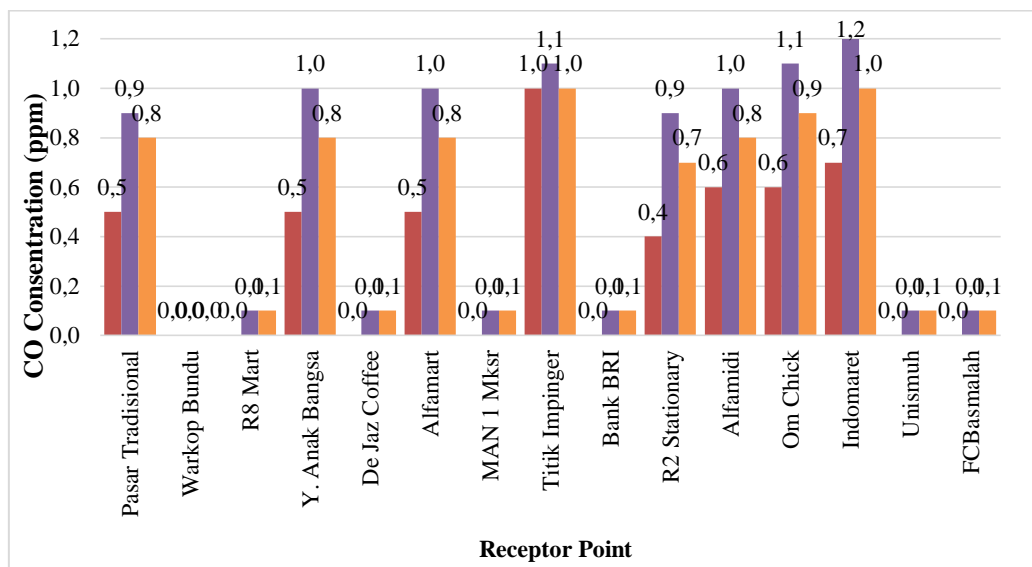
Table 3. CO concentration from direct measurements.

Road	Day	Date	Concentration		Quality standards	
			ppm	$\mu\text{g}/\text{Nm}^3$	$\mu\text{g}/\text{Nm}^3$	Period
Urip Sumoharjo	Tuesday	May 21, 2019	3.10	3,547.81	30,000	1 hour
	Wednesday	May 22, 2019	4.05	4,635.04	30,000	1 hour
	Thursday	May 23, 2019	5.80	6,637.84	30,000	1 hour
Talasalapang	Tuesday	June 18, 2019	1.01	1,155.81	30,000	1 hour
	Wednesday	June 19, 2019	1.03	1,183.40	30,000	1 hour
	Thursday	June 20, 2019	1.06	1,212.63	30,000	1 hour
Nusantara	Tuesday	June 25, 2019	1.00	1,140.67	30,000	1 hour
	Wednesday	June 26, 2019	1.15	1,310.71	30,000	1 hour
	Thursday	June 27, 2019	1.05	1,200.27	30,000	1 hour

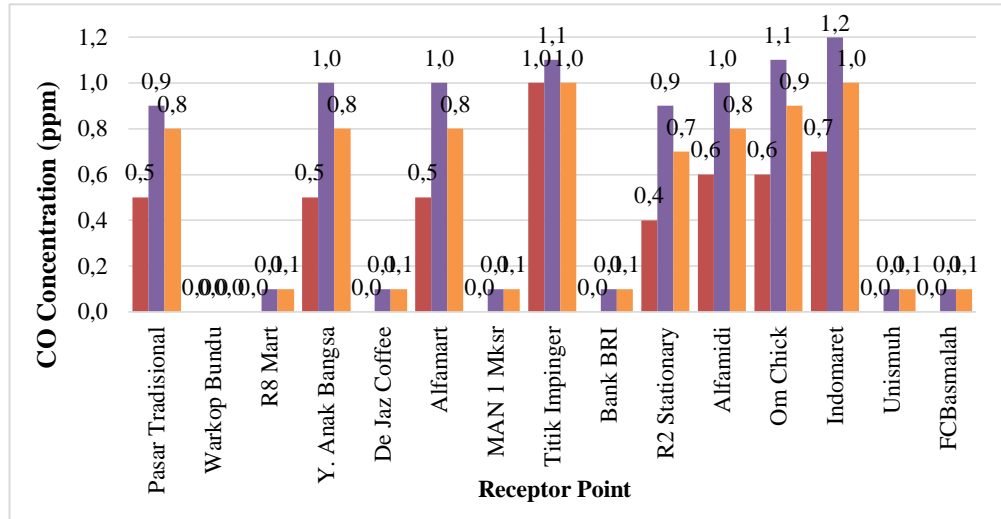
Based on Table 3, the CO concentration values on Urip Sumoharjo Street, Talasalapang Street and Nusanatara Road for one hour during the three days of measurement were still within the threshold required by Government Regulation No.41 of 1999 concerning Air Pollution Control, which is $30,000 \mu\text{g}/\text{Nm}^3$. This shows the concentration of CO in several roads in Makassar City are still safe and do not endanger health. The results of these different CO concentrations are influenced by various factors such as meteorological conditions such as temperature, wind speed and traffic characteristics on each road in different days. On Jalan Urip Sumoharjo the results of CO concentrations on Tuesday to Thursday tends to increase even though the vehicles volume do not increase. This is due to meteorological factors where the wind speed on Tuesday to Thursday tends to decrease so that the CO concentration on Tuesday to Thursday increases. Similarly, the CO concentration results obtained on Talasalapang road and Nusantara road. The faster the wind speed in an area, the mixing of pollutants from the source of emissions will be greater, resulting in the occurrence of dilution that causes pollutants in the area will decrease. In addition to the meteorological factor of wind speed, air temperature is also one of the CO concentration values. On Talasalapang road and Nusantara road, CO concentration values tend to increase with increasing air temperatures. This is because high temperatures will cause pollutants in the air to dry up so pollutants tends to be higher.

3.3 Estimated Distribution of CO

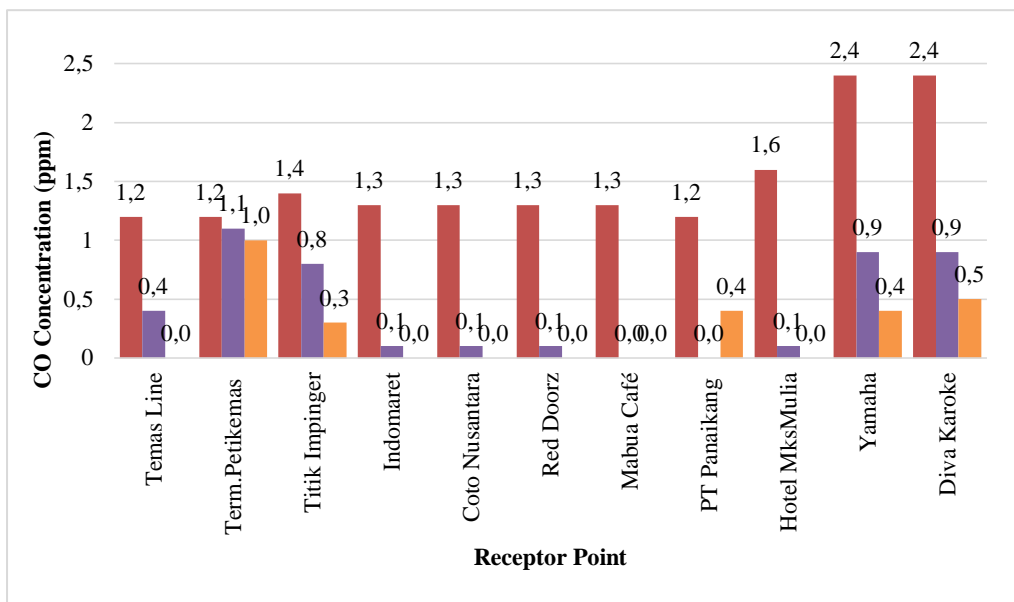
To estimate the distribution of CO which has been dispersed into free air and the magnitude of the impact of pollutants received at each receptor on Jalan Urip Sumoharjo, Talasalapang Street, and Nusantara road, a Caline4 software can be used.



(a) Talasalapang



(b) Urip Sumiharjo



(c) Nusantara

Figure 3. Estimation of CO distribution using caline on each road.

Figure 3a shows that on Tuesday at Talasalapang road the highest CO concentration was at the impinger point of 1.0 ppm or 1,144.45 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was 0.0 ppm at some receptor points. The highest estimation of CO concentration on Wednesday at Talasalapang road was at the indomaret receptor point of 1.2 ppm or 1,373.35 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was 0.0 ppm at some receptor points. The highest estimation of CO concentration on Thursday at Talasalapang road was at the impinger point of 1.0 ppm or 1144.45 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pp pollutant concentration was 0.0 ppm at some receptor points. In Figure 3b, it shows that on Tuesday at Urip Sumoharjo the highest CO pollutant concentration was at the tirta swimming pool receptor point which was 3.4 ppm or 3,891.15 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was at the coffee lovers receptor point namely of 1.1 ppm or 1,258.90 $\mu\text{g}/\text{Nm}^3$. The highest CO concentration estimation results on Wednesday at Urip Sumoharjo was at the tirta swimming pool receptor point which was 4.9 ppm or 5,607.83 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was at the coffee lovers receptor point which was 1.2 ppm or 1,373.35

$\mu\text{g}/\text{Nm}^3$. The highest CO concentration estimation results on Thursday at Urip Sumoharjo was at the tirta swimming pool receptor point at 6.0 ppm or 6,866.73 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was at the Nurul Ittihad Mosque receptor point which was 2.9 ppm or 3,318.92 $\mu\text{g}/\text{Nm}^3$. In Figure 3c, it shows that on Tuesday at Nusantara Street the highest CO pollutant concentrations were at the Yamaha and Diva Karoke receptor points which were 2.4 ppm or 2,746.69 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentrations were at the Temas Line receptor point and Container Terminal is 1.2 ppm or 1,373.35 $\mu\text{g}/\text{Nm}^3$. The highest estimation of CO concentration on Wednesday in Nusantara Street was at the container terminal receptor point which was 1.1 ppm or 1,258.90 $\mu\text{g}/\text{Nm}^3$, while the lowest CO pollutant concentration was 0.0 ppm which was at the Mabua Cafe receptor point and PT. Panaikang Intimate. The highest estimation of CO concentration on Thursday at Nusantara Street was at the impinger point of 1.0 ppm or 1,144.45 $\mu\text{g}/\text{Nm}^3$, while the lowest concentration of CO pollutant was 0.0 ppm at some receptor points.

From these results, it shows that the value of CO concentration based on the results of the Caline4 software output depends on the input variables, including vehicle volume, wind direction and speed, and others. The value of CO concentration is influenced by the volume of vehicles, vehicles produce the most CO than other sources, especially gasoline-powered vehicles, the more vehicles the greater CO is produced. CO concentration is also influenced by meteorological factors such as wind direction, wind speed and atmospheric stability. The higher the value of the wind speed, the concentration of CO pollutants dispersed will be smaller. Unstable atmospheric conditions were beneficial in dispersing pollutants, because pollutants were immediately dispersed with the surrounding environment so that the receptors did not experience exposure to high pollutant concentrations. Stable atmospheric conditions are unfavorable to the receptor, because the receptor receives exposure to high pollutant concentrations. This shows that it is true that when atmospheric conditions are not stable, CO concentrations are higher.

3.4. Comparison of direct measurement and CALINE4-estimated CO concentrations

The CO concentration from direct measurements using impinger will be compared with Caline4 software. CO concentration from direct measurements using impinger and Caline4 software prediction results have different concentrations. Coinciding with [10], the difference is caused by several factors that are not taken into account by Caline4 software. The CO concentration of Caline4 software output results has a lower value than the direct measurement results [11]. The difference in the value of CO concentration results of direct measurements using impinger compared to the results of the Caline4 software output is because there are CO sources other than transportation activities that contribute to the results of CO measurements in the field using impinger. Caline4 software calculation takes into account CO emissions due to transportation and ignores other factors, whereas in direct measurements in the field, the measured CO is CO at the receptor point originating not only from transport activities but also from other sources.

Table 4. T-Test result.

Road	Day	CO Concentration (ppm)		t Stat	t Critical
		Impinger	Caline4		
Urip Sumoharjo	Tuesday	2.08	2.60	-2.167	4.303
	Wednesday	1.00	3.60		
	Thursday	1.01	5.70		
Talasalapang	Tuesday	1.01	1.00	0.032	4.303
	Wednesday	1.03	1.10		
	Thursday	1.06	1.00		
Nusantara	Tuesday	1.00	1.40	0.682	4.303
	Wednesday	1.15	0.80		
	Thursday	1.05	0.30		

Based on table 4, the difference from CO concentration data from impinger direct measurement results with Caline4 software results obtained by testing the t-stat <t-critical value. This shows that CO concentration data from impinger direct measurement with Caline4 software is statistically the same or there is no significant difference.

4. Conclusions

Based on the results of direct measurements using impinger, the CO concentration results are still at the required threshold value of 30,000 $\mu\text{g}/\text{Nm}^3$ with a measurement time of 1 hour. High or low CO concentration values are influenced by vehicle volume factors, where the CO concentration increases with increasing vehicle volume. In addition, also influenced by meteorological factors, the faster the wind speed in an area, the mixing of pollutants from the source of emissions will be greater, resulting in a dilution that causes pollutants in the area will decrease. The output of the impinger software output results in the CO concentration still being within the threshold value required by Government Regulation No. 41 of 1999 concerning ambient air quality standards of 30,000 $\mu\text{g}/\text{Nm}^3$ with a measurement time of 1 hour. The estimated results of CO pollutant concentrations are influenced by various factors, including link activity and run condition. The impinger CO concentration was the same as the CO concentration from Caline4 software which showed the t-stat value <t-critical. Thus it can be said that Caline4 software is considered capable of predicting CO concentrations at receptor points on the road.

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