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Analysis of NO_2 gas concentration from the transportation sector through direct measurement and the Caline 4 dispersion program on the Makassar City Toll Road

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Abstract. Makassar as a developing city is experiencing development from the transportation sector. This resulted in the increasing number of vehicles. The increase in the number of vehicles produces emissions that cause air pollution, including NO_2 emissions from motor vehicles. Currently NO_2 concentration can be determined by direct measurement using the Gries Saltman method and pollutant prediction using the Caline program. This research was conducted on the Makassar city toll road which is divided into nine sample points. This study aims to determine the level of NO_2 concentration from the transportation sector on the Makassar city toll road. Concentration results from direct measurements and predictions of caline are compared to show the level of concentration present. The results of the NO_2 concentration are still below the threshold value that has been set in the latest applicable regulations, which is 200 g/Nm^3 with a measurement time of 1 hour. The high or low value of NO_2 concentration is influenced by the vehicle volume factor, where the NO_2 concentration increases along with the increase in vehicle volume. In addition, it is also influenced by meteorological factors. Based on the results of the Caline-4 software output, the results obtained from the distribution of NO_2 concentrations at each receptor found on the Toll Road in Makassar City, it can be stated that it is still below the threshold value set in the latest applicable regulations, which is 200 g/Nm^3 with time measurement for one hour.

1. Introduction

Air quality is very important for the environment and human health. At both the local and global levels, air pollution is one of the most obvious contributors to negative externalities. At both the local and global levels, air pollution is one of the most obvious contributors to negative externalities. On a global scale, greenhouse gas emissions are a factor in climate change, meanwhile in local scale revealed that the current levels of air pollution seen in many cities are linked to health concerns [1]–[3].

Population growth, technological advances applied to combustion, industrial and agricultural processes, and the indiscriminate use of territory are causing the continuous evolution of atmospheric pollution characteristics, which need to be understood to intervene effectively [4]. Additionally, the growth of transportation in developing countries is contributing to the decreased of air quality [5].

Makassar is one of the big cities in Indonesia. A previous study stated that a dense population was found to be correlated to the use of vehicles [6]. Based on data obtained from the Makassar City Statistics Agency, the use of motorized vehicles in Makassar City has a ratio of 27.4% increase in the number of motorized vehicles, from 2011 as many as 976.004 units to 1,338,738 units in 2015 and in October 2018, vehicles reached 1,563,608 units [7].

Some previous study stated that the potential for air pollution was found to be higher due to the increasing use of vehicle fuels which could produce emissions from these vehicles. Vehicles' diesel exhaust is a major source of PM2.5, air hazardous pollutants, and NOx emissions (one of the precursors to ozone), all of which have the potential to be harmful to human health [8]. The concentration of each pollutant is also very dependent on the meteorological conditions of an area such as wind speed [9].

According to the background, the aim of this study is to know the distribution pattern of Nitrogen Dioxide (NO_2) and the estimation of the impact of the pollutant distribution of Nitrogen Dioxide (NO_2) received in the Makassar City Toll Road area by applying the Caline-4 program.

2. Material and method

2.1. Study Area

Makassar toll road was located in Makassar city which connects several important places such as Soekarno-Hatta Port, the city center, Panakkukang commercial center, Makassar Industrial Area, and Sultan Hasanuddin International Airport with a total length of 21.92 km. This toll road was divided into 2 area i.e. Jl. Toll Reformasi and Jl. Toll Insinyur Sutami.

There were 9 (nine) points of sampling point within Makassar City Toll road area, which were 3 points taken from Jl. Toll Reformasi and 6 points from Jl. Toll Insinyur Sutami. These sampling points were chosen to find out if there is a change in air quality at that point due to changes in vehicle volume every time there are openings on the toll road.

Figure 1. Study area and sampling Point (a) Jl. Toll Reformasi; (b) Jl. Insinur Sutami

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2.2. Sample collection, sample preparation, and analysis

Data was collected in 9 days from Tuesday, 27 April 2021 to Wednesday, 5 May 2021. Volume of vehicles and air sample for calculate the concentration of nitrogen dioxide (NO_2) emissions from vehicles were taken at each sampling points. Measurements were carried out for 1 (one) day with a measurement duration of 1 (one) hour by taking a representative of the peak hour at the afternoon interval between 15.00-18.00 WITA on the Makassar City Toll Road where it was assumed that the activity density of vehicles passing through the area was high.

Concentration of NO_2 was measured by took air sample on-site. However, according to SNI 19-7119.2-2005, that describes about the procedure for measuring the concentrations of nitrogen dioxide (NO_2) in ambient air, materials need to be prepared before data collection in the field such as adsorption solutions and calibration curves [10]. The adsorbent solution was prepared by dissolving 70 g of glacial acetic acid and 3 g of sulfanilic acid. Add 800 ml of distilled water after stirring. Lastly, added 20 ml of NEDA solution, 10 ml of acetone, and distilled water, then homogenized. Moreover, calibration curves was prepared by making standard solutions and measure their respective absorptions with a spectrophotometer. In this study, we used 0 mL, 0.1 mL, 0.2 mL, 0.4 mL, 0.6 mL, 0.8 mL, dan 1.0 mL as a standard solution for NO_2 concentration.

Impinger was used as a data collection tools. Moreover, the impinger migdet adsorbent bottle and silica bottle were used to store the adsorbent solution during the measurement process and to store silica which is connected to the adsorbent bottle to prevent moisture from entering the impinger, respectively. Air sample was taken and directly analyzed in laboratory.

2.3. Data analysis

Gasoline and diesel are two different types of fuel released by engines found in vehicles and have almost the same pollutant composition. In addition, the value of the emission factor was directly proportional to the amount of pollutants contained by the combustion residues released by vehicles on the road.

In this study, the emission factor value for the metropolitan area was assumed from the exhaust gas emission factor value based on the type of vehicle and the type of fuel. The calculation of the emission factor value has been regulated and stipulated by the government in PerMen LH No. 12 of 2010 which regulates the Implementation of Air Pollution Control in the Regions [11]. The quantity of emissions produced by each type of vehicle was calculated by using equation 1.

$$q = \frac{\sum_{i=1}^{n} (\text{EFi x Vi})}{\text{T}} \qquad \text{(Equation 1)}$$

Where: q = Emission Quantity (gram/km); EF = Vehicle Emission Factor (grams/km); V = Vehicle Volume (vehicles/hour); I = Vehicle Type/Type; and T = Total Vehicle

2.4. Simulation the dispersion of NO_2

In this study, first the data will be analyzed using WRPLOT software by inputting time data and meteorological data when conducting research. This software serves to determine the condition of the wind direction and the dominant wind speed [12]. Afterwards, data will be processed by applying Caline-4 software. CALINE-4 is a program that can simulate air quality from line sources to estimate the dispersion of a pollutant [13]. The application of this software was carried out to get the results of the estimation of the amount of NO_2 pollutant around the sampling point which was used as a receptor point. The files that were inputted in this software were Job Parameters, Run Conditions, Link

Geometry, Link Activity, Receptor Position, and 1 output, namely result. The last step was by using software Golden surfer 11. This application was used to determine the distribution pattern of NO_2 pollutants on each road segment at the research site.

3. Result and discussion

3.1. Traffic volume studies

One of the major sources of air pollution in this study area is vehicular emissions. The numbers of vehicle number is determined by carried out for 1 (hour) data collection from each point. The measurement is carried out by taking representatives of peak hours in this case occurring at the afternoon interval, which is between 15.00-18.00. Motor vehicles are divided into motorcycles (MC), gasoline cars (LV Gasoline), diesel cars (LV Solar), trucks, and buses. This grouping by type is done to make it easier when calculating the volume of motorized vehicles expressed in vehicles per hour. The results of data collection of traffic volume can be seen in the following figure 2.

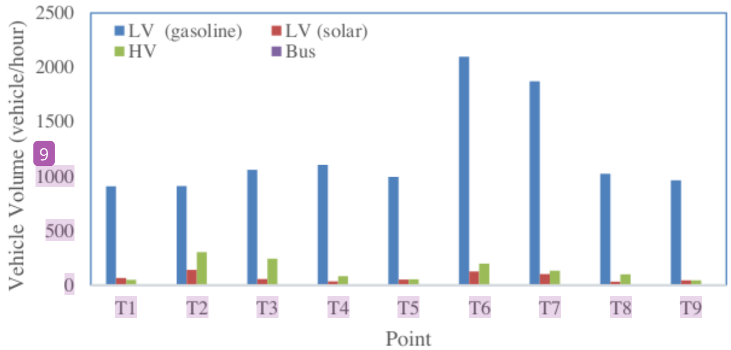

Figure 2. The number of vehicle volume

Based on the vehicle volume figure above, it can be seen that the maximum LV Gasoline vehicle volume is at the T6 observation point as much as 2099 units/hour with a percentage of 19.21%. For the minimum LV Gasoline volume at the observation point T1 as much as 907 units/hour with a percentage of 8.30%. The maximum LV Solar volume is at the T2 observation point as much as 138 units/hour with a percentage of 21.73%. The minimum LV Solar volume is at the observation point T8 as much as 30 units/hour with a percentage of 4.72%. The maximum HV volume is at the observation point T2 as much as 303 units/hour with a percentage of 25.36%. The minimum HV volume is at the observation point T9 as much as 43 units/hour with a percentage of 3.60%. Meanwhile, the bus volume is only at points T2 and T6 as much as 1 unit/hour with a percentage of 50%. The number of vehicle volume and dthe fuel consumption must be determined because traffic emissions are directly related to the fuel consumption of each vehicle. It caused by incomplete combustion process in the engine system [14].

3.2. Vehicular emissions

The value of the amount of emission for each type of vehicle is obtained from the calculation results of measuring the volume of vehicles on the toll road that passes at each measurement point. Calculation of the value of the amount of emission for each type of vehicle using the emission factor. The results of emission from vehicle can be seen in the following figure 3 and figure 4.

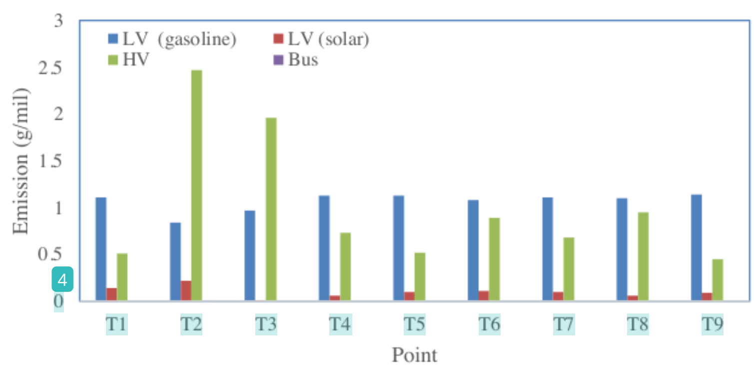

Figure 3. NO_2 emissions by type of vehicle

Based on Figure 3, it can be seen that the highest amount of NO_2 emission is 3.53 gr/mile at T2, while the lowest emission 1.68 gr/mile. Based on the value of the amount of emission, it can be seen that the value of the amount of emission based on the value of the emission factor is influenced by the volume of vehicles of each different type of motorized vehicle.

Gasoline-fueled vehicles (LVb) are the most dominant types of vehicles that contribute to NO_2 emissions, which is 48.62%. Truck type vehicle (HV) is the type of vehicle that contributes the second highest NO_2 emission at 46.47%. Diesel-fueled vehicles (LVs) contributed 4.87% of NO_2 emissions while Buses (BS) contributed 0.04% of NO_2 emissions.

Each type of vehicle that contributes different amounts of emissions is influenced by differences in vehicle volume and emission factors. The high volume of LVb vehicles makes the value of the emission load contributed by LVb is also large. This shows that on the Toll Road in Makassar City, the dominant vehicle passing is the LVb type vehicle, which is 48.62%. the emission load of each type of vehicle at each point is then averaged. The average value of the emission load at each point can be seen in the following figure 4.

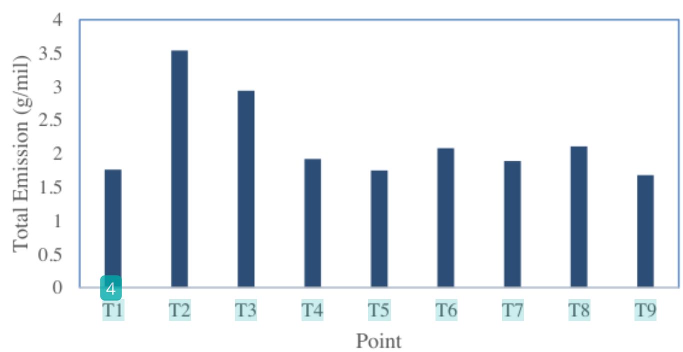

Figure 4. Emission load per point

From figure 4, the highest average concentration was obtained for 1 hour of measurement, which was 97.1 g/Nm^3 at T3, and the lowest average concentration was 30.3 g/Nm^3 at T1. The value of NO_2

concentration based on the output of Caline-4 software is influenced by the input variables, namely vehicle volume, wind direction and speed, background concentration, photolysis rate, and NO_2 ratio.

3.3. NO_2 concentration by direct measurement

Measurement of NO_2 concentration in ambient air is carried out using an impinger with one impinger measurement point or sampling point on each road. Test method for nitrogen dioxide (NO_2) levels using the Griess Saltzman method using a spectrophotometer. Concentration results from direct measurements at each point can be seen in Figure 5.

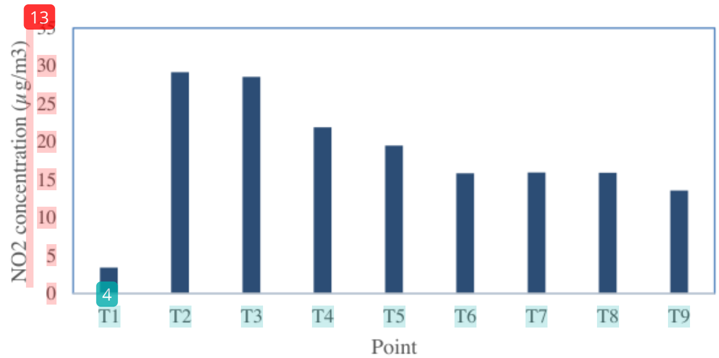

Figure 5. Concentration of direct measurement results at each point

3.4. NO_2 concentration prediction

Prediction of the spread of NO_2 pollutants that experience dispersion into free air with pollutants contained in each receptor on the Toll Road area in Makassar City using a software called Caline-4. The data used to operate the Caline-4 is different for each parameter. For the NO_2 parameter, data on background concentrations of O_3, NO, and NO, the ratio of NO_2/NOx, and the appropriate rate of NO_2 photolysis are required. The concentration results of Caline-4 are in ppm which will then be converted to g/Nm^3 for comparison with ambient quality standards. NO_2 Concentration Prediction results can be seen in Figure 6.

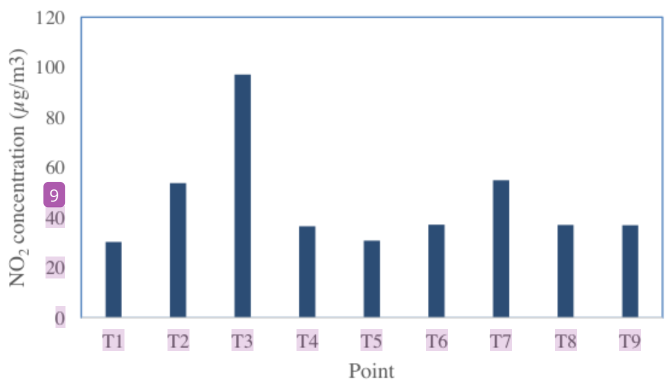

Figure 6. NO_2 concentration prediction

3.5. Comparison of NO_2 concentration from measurement results and caline dispersion

A recapitulation of the pollutant concentration of nitrogen dioxide (NO_2) direct measurement using impinger and Caline-4 can be seen in Figure 7

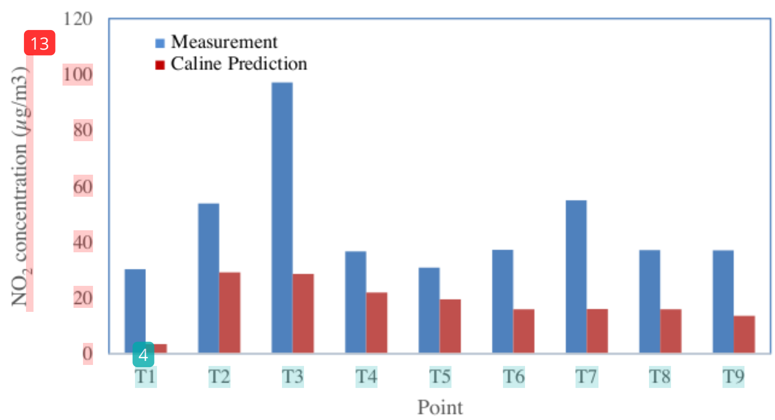

Figure 7. Comparison of pollutant concentrations of nitrogen dioxide (NO_2)

The concentration of Nitrogen Dioxide (NO_2) from caline 4 was higher than direct measurement using impinger. Caline-4 tends to be influenced by factors from transportation and the most important is the use of emission factors that affect the calculation of average emissions and the existing traffic volume.

4. Conclusion

In accordance with the results of measurements that have been carried out directly on the Toll Road in Makassar City using the impinger tool, the results of the NO_2 concentration are still below the threshold value that has been set in the latest applicable regulations, which is 200 g/Nm^3 with a measurement time of 1 hour. The high or low value of NO_2 concentration is influenced by the vehicle volume factor, where the NO_2 concentration increases along with the increase in vehicle volume. In addition, it is also influenced by meteorological factors. Based on the results of the Caline-4 software output, the results obtained from the distribution of NO_2 concentrations at each receptor found on the Toll Road in Makassar City, it can be stated that it is still below the threshold value set in the latest applicable regulations, which is 200 g/Nm^3 with time measurement for 1 hour.

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