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Effect of Wind Angle Direction on Carbon Monoxide (CO) Concentration Dispersion on Traffic Flow in Padang City

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Abstract. This study aims to analyze the relationship between CO concentration and wind direction. Wind direction in this context is the wind angle to the road on the traffic flow in Padang City. Sampling of CO concentration was conducted for 9 days at 3 monitoring points (each 3-day point) representing the wind angle to the road (α) i.e. at Jend. A. Yani road (0 degrees), Andalas road (30 degrees) and Prof. Dr. Hamka road (60 degrees), using impinger and analyzed by spectrophotometer. The results of the research in the three monitoring sites showed that the concentration of CO ranged between 137.217 and 600.525 $\mu\text{g}/\text{Nm}^3$. The highest and lowest concentrations respectively on Prof. Dr. Hamka road and Jend. A. Yani road. The sampling showed that CO concentrations will be decreased if wind direction is changed from perpendicular wind direction (α 90°) to α 60°, 30°, and 0° respectively by 64.62%, 37.77% and 27.09%. It can be concluded that the wind angle direction to the road affects the CO concentrations in the roadside.

1. Introduction

Population in Padang City continues to grow up every year. The increase in population leads to enhance in the number of transportation. The number of motor vehicles in Padang City rise up about 39.8% between 2012 and 2014 [1]. Increasing the number of vehicles impacting air quality in Padang City, one of which enhance the concentration of carbon monoxide (CO) [2]. One of the factors affecting air pollutant concentration is meteorological factor, such as wind direction and wind speed [3]. Wind direction and wind speed determine the spread of CO from the transport sector. The dominant wind direction will carry and distribute the pollutant [4].

CO is a poisonous, colorless, odorless, and tasteless gas. CO is resulting from the incomplete burning of natural gas and any other material containing carbon, that sources from the internal combustion engine [5]. This gas is hazardous on human respiratory health [6]. CO in formation of carboxyhemoglobin (COHb) also contributes to decrease O₂ level in blood system [7].

Some studies have been done to determine the CO concentration on the roadside area [8], [9], [10]. In these studies, monitoring were conducted on the roadside that are perpendicular to the dominant wind direction [2], which refers to [11]. However, it is not all off roads are perpendicular to the dominant wind direction, so it is necessary to monitor the influence of the dominant wind direction on Carbon Monoxide (CO) dispersion on roadside area.



The purpose of this research is to determine the effect of wind angle to the road, toward CO concentration in the roadside area. The wind angle to the road (hereinafter called α) used in this research are 0° , 30° , and 60° .

2. Methods

2.1 Secondary data collection

Secondary data required in this research are the map of road network of Padang City, traffic characteristic data, wind direction and wind speed data. Wind direction and wind speed were gotten from the Meteorology, Climatology and Geophysics Agency (BMKG) Padang City for years 2012-2016 which will be useful to determine the dominant wind direction, then, this meteorological data will be used as a wind angle reference point of zero degrees.

2.2 Primary data collection

Primary data collected include meteorological conditions, CO concentrations and traffic characteristics. Meteorological conditions measured are temperature (K) and air pressure (mmHg) using pocket weatherman, wind velocity (ms^{-1}) using an anemometer and wind direction using compass. Sampling of CO concentrations is conducted for 1 hour measurement. Sampling of CO was done at 3 points representing wind coming angle to road (α) (see Figure 1), namely at Jend. A. Yani Road with α is 0° , Andalas Road with α is 30° and Prof. Dr. Hamka Road with α is 60° . α values range between 0° and 90° .

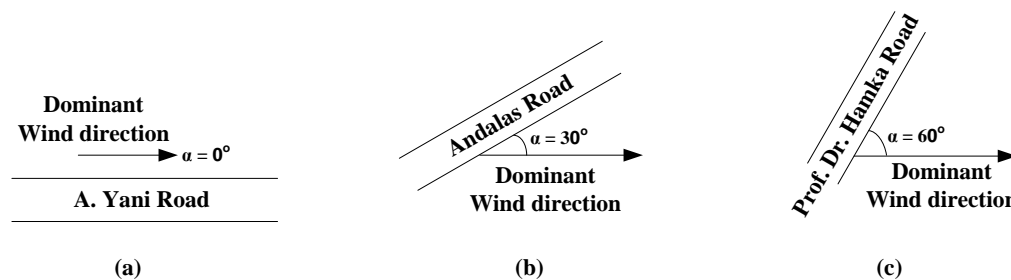


Figure 1. sketches of wind angle direction to the road

Measurement of CO using impinger and CO analysis using spectrophotometer. The sampling of CO concentrations was conducted for 9 days for 3 monitoring points. Each monitoring point sampling was conducted for 3 days with measurements every 1 hour for 10 hours/day starting at 07.00- 17.00. Total samples collected for 3 points were 90 samples. Measurement of traffic characteristics including traffic volume, traffic speed and traffic density, which were carried out in conjunction with the measurement of CO concentrations. Measurement of the number of vehicles in 3 CO monitoring locations is done manually at the sampling point using counter.

2.3 Data analysis

Data analysis includes comparison of CO concentration measurement with national air quality standard, analysis of CO concentration relationship with traffic characteristics, such as traffic volume, traffic speed and traffic density. Finally, analyze the decrease in CO concentration due to changes in the wind angle to the road.

3. Results and discussion

3.1. CO concentrations and national air quality standard

The result of CO measurement can be seen in Figure 2. The highest concentration is at Prof. Dr. Hamka Road is $600,525 \mu\text{g}/\text{Nm}^3$ and the lowest concentration is at Jend. A. Yani Road equal to $137,053 \mu\text{g}/\text{Nm}^3$. The highest CO concentrations for the three study sites were at 16.00-17.00.

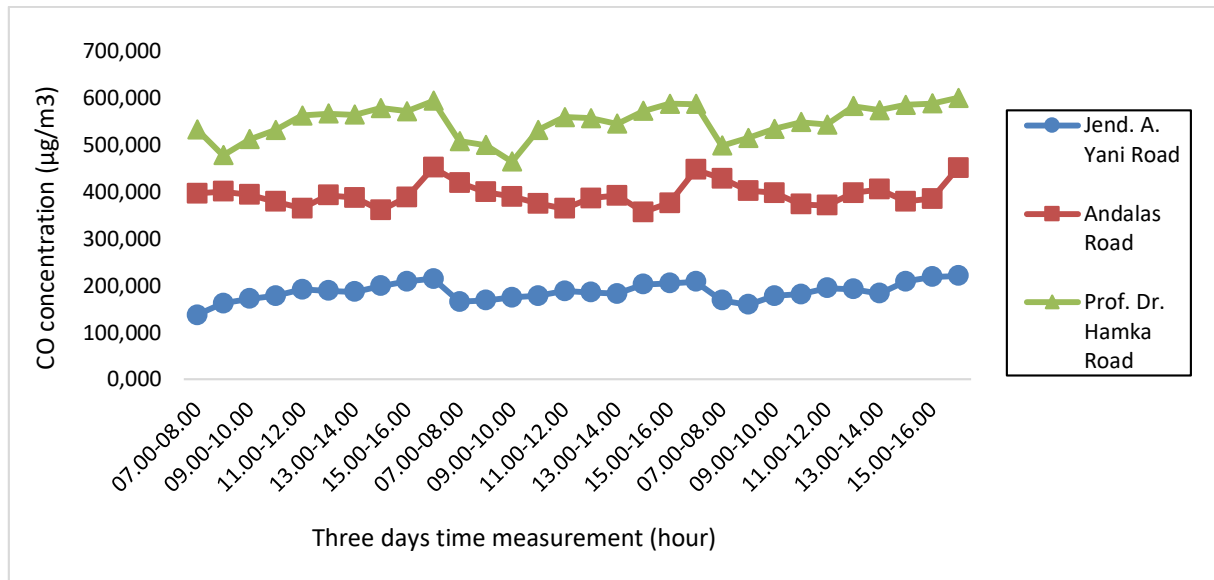


Figure 2. CO Concentrations in Three Monitoring Location

Based on [12], the maximum concentration of CO in ambient air can be tolerated by 30,000 $\mu\text{g}/\text{Nm}^3$ for 1-hour measurement. Based on the measurements of CO concentration at all three monitoring locations, the CO concentration is still below the standard in [12]. This means, CO on the roadside area in Padang City does not endanger human health.

3.2. Correlation analysis between co concentration and traffic characteristics and wind speed

Traffic volume is one of the traffic characteristics that influences CO concentrations in the atmosphere. The correlation between CO concentration and traffic volume can be seen in Figure 3.

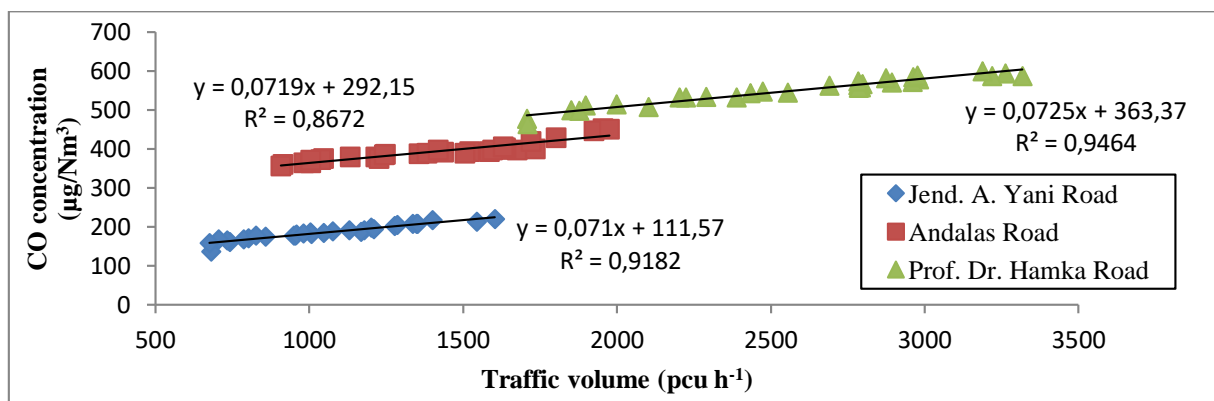


Figure 3. Correlation between CO Concentration and Traffic Volume

Based on Figure 3, it can be seen that the relationships between the concentration of CO in the three research sites and traffic volume are very strong, with the value of R^2 on Jend. A. Yani Road is 0.9182, on Andalas Road is 0.8672 and on Prof. Dr. Hamka Road is 0.9464 respectively. Meanwhile, the R value of each location are 0.958 on Jend. A. Yani Road, 0.931 on Andalas Road and 0.973 on Prof. Dr. Hamka Road. The correlation indicates that CO concentration is directly proportional to traffic volume, it means that the higher traffic volume will bring about the higher CO concentration and vice versa [2].

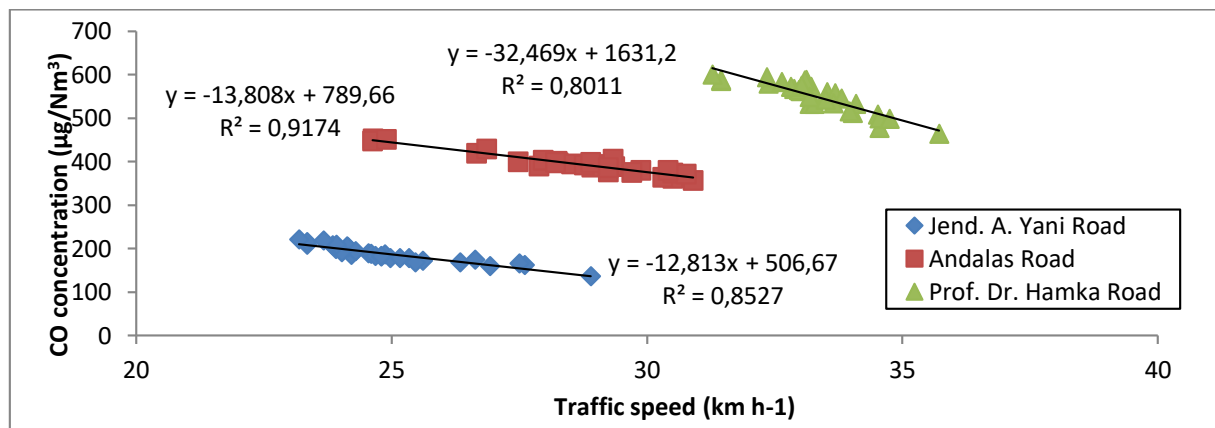


Figure 4. Correlation between CO Concentration and Traffic Speed

Figure 4 show the relationship between CO concentration in the three research sites and traffic speed. It can be seen that correlations are very strong, with the value of R^2 are 0.8527 (on Jend. A. Yani Road), 0.9174 (on Andalas Road) and 0.8011 (on Prof. Dr. Hamka Road). Meanwhile, R value is -0.923 on Jend. A. Yani Road, -0.958 on Andalas Road, and -0.895 on Prof. Dr. Hamka Road. R values in the three study sites indicate a strong negative correlation between CO concentration and traffic speed. This correlation shows the inverse relationship between CO concentration and traffic speed. If the vehicle speed gets higher, the CO concentration will be lower. If the vehicle speed gets higher, the CO concentration will be lower. This is in accordance with the research conducted [13], that there is a negative strong relationship between CO concentration and traffic speed.

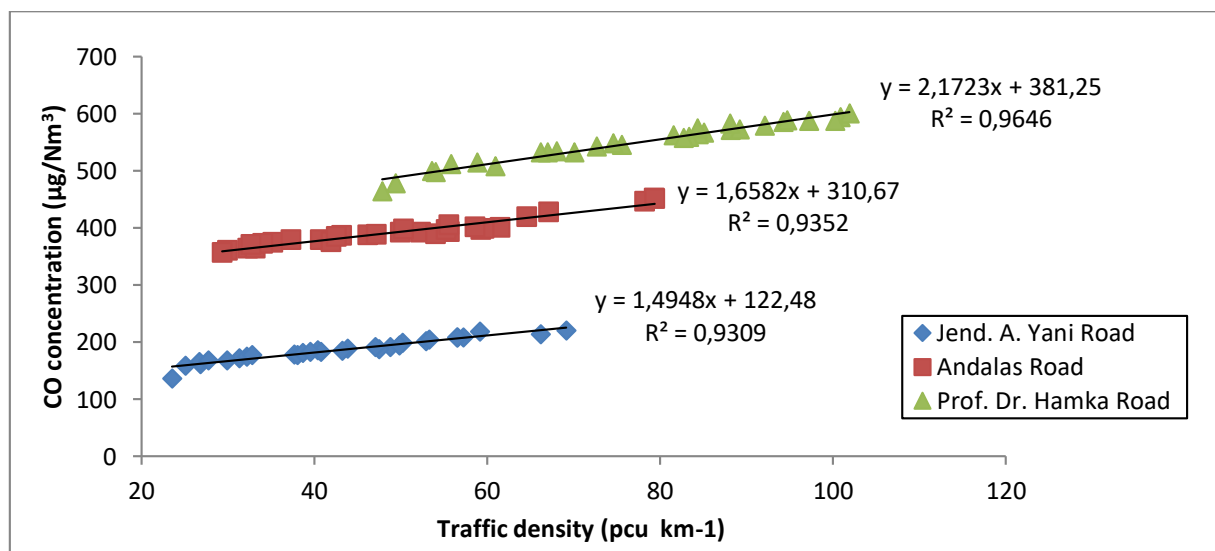


Figure 5. Correlation between CO Concentration and Traffic Density

Based on Figure 5, we can see the relationship between CO concentration in the three research sites and traffic density are very strong with R^2 on Jend. A. Yani Road is 0.9309, on Andalas Road is 0.9352 and on Prof. Dr. Hamka is 0.9646 respectively. Meanwhile, the r value of each location are, on Jend. A. Yani Road is 0.965, on Andalas Road is 0.967 and Prof. Dr. Hamka Road is 0.973. r values in the three study sites indicate a very strong reinforcement between CO concentration and traffic density.

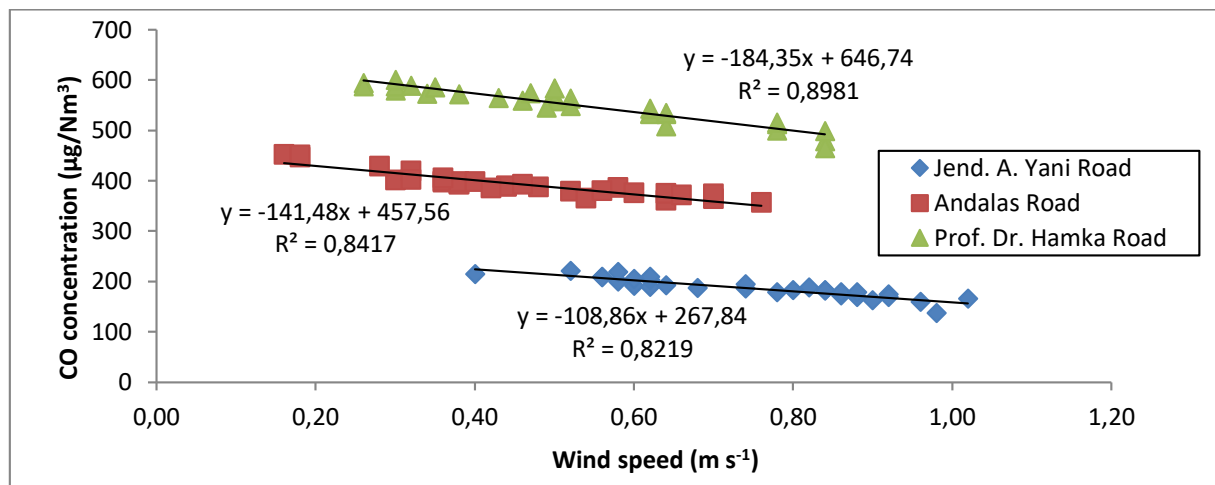


Figure 6. Correlation between CO Concentration and Wind Speed

Correlation between CO concentration and wind speed is shown in Figure 6. It can be seen that the relationship between CO concentrations in the three research sites and wind speed are very strong with the value of R^2 respectively are, on Jend. A. Yani Road equal to 0.8219, on Andalas Road equal to 0.8417 and on Prof. Dr. Hamka Road equal to 0.8981. At the time same, r value of each location is -0.907 on Jend. A. Yani Road, -0.917 on Andalas Road and -0.948 on Prof. Dr. Hamka. r values in the three research sites indicate a very strong negative correlation between CO gas concentration and wind speed. This correlation shows the inverse relationship between CO gas concentration and wind velocity passing through the study site. If wind speed is higher, then CO concentration will be lower. This is in accordance with the research conducted by [14] [15] [16], the relationship between wind speed and pollutant concentration is inversely proportional.

3.3. Reductions of CO concentration against α (the angle between wind direction and the road)

One of the factors affecting CO concentration at vehicle emission dispersion is the angle between dominant wind direction and the road [17]. Wind angle to the road affects the level of pollution on the roadside. For more details, it can be seen in Figure 7 and Figure 8.

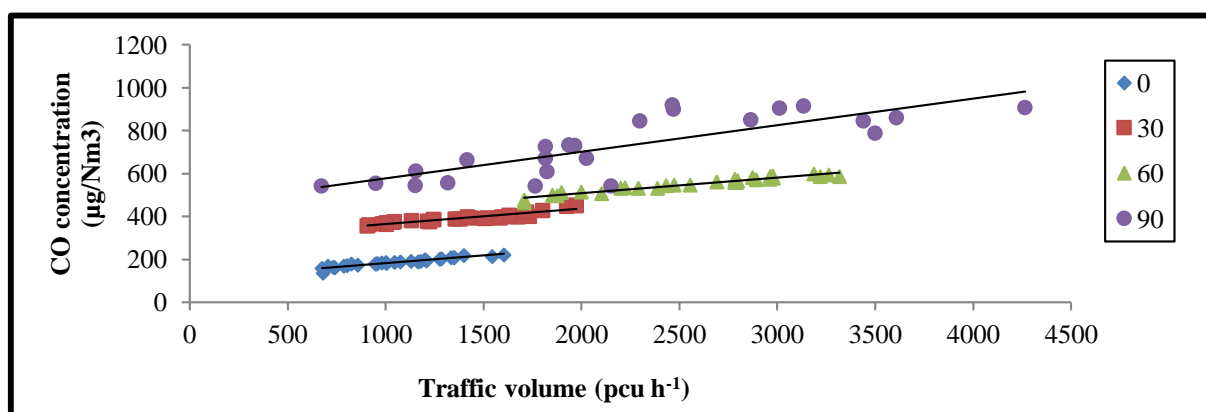


Figure 7. Reduction of CO Concentration against α on Traffic Volume

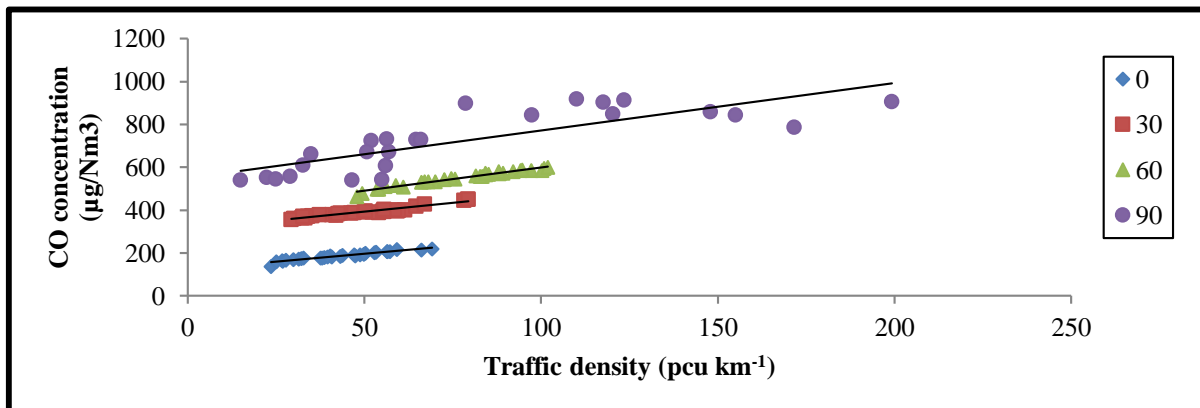


Figure 8. Reduction of CO Concentration against α on Traffic Density

Based on Figure 7 and Figure 8, there can be a decrease of CO concentration on traffic volume from $\alpha = 90^\circ$ to 60° by 27.09%, $\alpha = 90^\circ$ to 30° by 37.77% and $\alpha = 90^\circ$ to 0° by 64.62%. Meanwhile, based on traffic density $\alpha = 90^\circ$ to 60° equal to 22.95%, $\alpha = 90^\circ$ to 30° equal to 38.61% and $\alpha = 90^\circ$ to 0° equal to 65.50%. This means that the dominant wind angle can affect CO concentration in the roadside area [17].

4. Conclusion

The relationship of CO concentration to vehicle speed and wind speed is inversely proportional. The relationship of CO concentration to traffic volume, traffic density, and the angle of wind coming to the path (α) is directly proportional. CO concentrations at three sampling points are still below the national air quality standard. The highest concentration is obtained at the highest α (90°) and the lowest concentration is gained at the lowest α (0°). CO concentrations decreased most significantly from $\alpha = 90^\circ$ to $\alpha = 0^\circ$ is about $\pm 65\%$.

Acknowledgements

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