Influence of predominant wind angle direction to CO concentration in the surrounding area of cement industry

V S Bachtiar*, S Raharjo, R A Regia and Y Saputra
Environmental Engineering, Andalas University, Padang, Indonesia

*verasurtia@eng.unand.ac.id

Abstract. This study aims to determine the effect of predominant wind angle on the concentration of CO received by receptors (receptor position) due to the cement industry. This research was conducted in the surrounding area of the cement industry in Padang City. The sampling of CO concentration was undertaken at 3 sampling points, that is Unand Blok D Residence, Padang Besi Residence, and Batu Gadang Residence, that is representing of the receptor positions (α), i.e. 0°, 45° and 90°. In addition, sampling was also conducted at background point in Bukit Sungkai, Batu Busuk, Padang City. Sampling CO concentration at 4 sampling points using an impinger. The sampling of each location was done every hour for 24 hours of measurement (24 data per sampling point), with a total of 96 data. The results showed CO concentrations range between 124,502 and 287,292 μg/Nm³. The highest concentration was found at α 0° (Unand Blok D Residence) while the lowest concentration was located at α 90° (Batu Gadang Residence). Meanwhile, CO concentrations in the background point (Bukit Sungkai, Batu Busuk) is relatively lower than the three-sampling point above, ranging from 44.22 μg/Nm³ up to 74.13 μg/Nm³. The decrease in CO concentration on wind coming angle occurred from 0° to 45° by 13.79% and α 0° to 90° by 25.38%. This decrease happened by shifting α from 0° to 90°. This indicated that there is an effect of predominant wind angle direction towards CO concentration received by the receptor.

1. Introduction
One of the factors that influence air pollution in big cities is industrial activity. The cement industry is one of the industrial activities that affect air pollution. Pollutants produced by cement industry are dust, Sulphur oxides (SOx), nitrogen oxides (NOx) and carbon monoxide (CO) [1]. Some studies reported that cement industry affected crop and plants [2,3], increased greenhouse gas emission [4,5], and affected human health [6].

Cement industry uses coal in its operation and coal combustion produces CO pollutant. In West Sumatera, there is a cement industry that has contribution to air pollution. In the cement industry, source of air pollution is derived from milling raw materials, mining operations, coal mill, combustion, cement mill, cement packing and transportation of cement [7].

Hosseinibalam and Hejazi found that meteorological factors are the most important factor contributing to air pollution concentrations [8]. There are correlations between CO levels and meteorological parameters, especially temperatures and pressure. Meteorological factors also affect pollutant concentrations that is received by the receptor, they are wind speed [9], and wind direction [10]. The highest pollutant concentrations will occur in the downwind position of predominant wind direction.
This study aims to determine the effect of predominant wind angle on the concentration of CO received by receptors (receptor positions) due to cement industry.

2. Method
This study consists of several stages, namely meteorological data collections, sampling of CO concentrations, and CO concentration analysis.

2.1. Meteorological data collection
The tool used in sampling meteorological conditions is Pce-Fws 20 Meteorological Station. Pce-Fws 20 Meteorological Station detects wind direction, wind speed, air temperature and temperature and rainfall intensity. This meteorological data can be sent via radio waves from distances of up to 100 meters. All meteorological parameters are recorded on the monitor on the device. Fig. 1 shows the equipment used for measuring meteorological conditions.

![Figure 1. Meteorological instrument.](image)

2.2. CO sampling
Sampling of CO concentrations is conducted using impinger with analysed by spectrophotometry. Calculation of CO concentrations using formula 1.

\[
C = \frac{a \cdot V \cdot T \cdot (760 \text{ mmHg}) \cdot BM \cdot 10^6}{F \cdot L \cdot P \cdot (298^\circ K) \cdot (24.45 \text{ L/mole})}
\]

Where \( C \) is CO concentration (µg / Nm³), \( V \) is volume of final solution (L), \( a \) is a gas from a test sample based on a calibration curve, \( T \) is temperature (K), \( BM \): molecular weight (g/mole), \( F \) is average air flow rate (L/minute), \( t \) is time (minutes), and \( P \) is air pressure (mmHg).

2.3. Sampling locations and points
Sampling of CO concentrations is conducted every 1 hour for 24 hours measurement. Sampling of CO was done at 3 point representing the angle of predominant wind angle coming angle to the sampling location (\( \alpha \)), namely Unand Blok D Residence with \( \alpha \) is 0°, Padang Besi Residence with \( \alpha \) is 45°, and Batu Gadang Residence with \( \alpha \) is 90°. The three angles are chosen to see the change in CO
concentrations caused by wind direction, because the wind direction is very influential in the direction of distribution, transportation and dispersion of pollutants in the air and fluctuations in the concentration of pollutants in the atmosphere. The location of sampling Points and sketches of wind angle direction to the receptor’s position can be seen in Figure 2 and Figure 3, respectively.

Figure 2 illustrates that during the day the dominant wind blows from the West, whereas at night it blows from the East [7].

![Figure 2. Sampling locations.](image)

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### 3. Results and discussion

#### 3.1. Meteorological conditions

Meteorological conditions are an important factor to analysed pollutant concentrations [11]. Meteorological conditions during measurement can be seen in Figures 3, 4 and 6, which are temperature, relative humidity and air pressure, respectively.
Figure 4. Temperature.

Figure 4 shows temperature in the sampling locations. It can be seen that temperature in the day range between 25.98°C and 35.13°C. Meanwhile, temperature in the night range between 24.45°C and 31.28°C. The presence of sunlight makes the daytime temperature is higher than at night. The average temperature at the sampling location is 28.96°C. This is slightly higher than the temperature in Padang City two years ago which was only 26.30°C [12]. This is likely due to an increase in pollutant concentrations from year to year in Padang City. In contrary, figure 5 shows that relative humidity in the night is higher than in the day.

Figure 5. Relative humidity.
Figure 6 shows relationship between temperature and relative humidity. It can be seen that humidity will decrease with the rise of temperature, and vice versa.

High or low air pressure is depending on the height of the sampling location from sea level. A high location from sea level has a lower air pressure than the lower location, and vice versa. Air pressure in all three locations is relatively similar, because the three locations are at almost similar height from the sea level (see Figure 7).

3.2. CO concentrations
CO concentrations at three sampling locations is shown in Figure 8. As can be seen that Unand Blok D Residence has the highest concentration, followed by Padang Besi Residence and Batu Gadang Residence. CO concentration received by receptor is influenced by the dominant wind direction. In this case, Unand Blok D Residence is passed by dominant wind direction, meanwhile Padang Besi Residence and Batu Gadang Residence, form an angle to the dominant wind direction, so that CO concentration that are received by receptor are lower. Fig. 7 also shows that CO concentration in the background site (Sungkai) is very low compared with the three sampling locations. CO concentration in the background site also lower than CO concentration produced by transportation [13]. It is caused by Sungkai do not influenced by pollutants from industry either from transportation. Bachtiar et al. found that pollutant
concentrations are influenced by temperature, however, this did not occur in this study because at night the concentration increased and was inversely proportional to temperature [14,15].

![Figure 8. CO concentrations.](image)

3.3. CO reductions
One of the factors that influence the value of CO concentration in the receptor position is the dominant wind angle. The concentration will be even greater if the wind angle to receptor position near 0°. It shows that the larger angle that formed between the dominant wind, the source of pollutants and receptors, the concentration received by the receptor will be smaller [14]. The reduction in CO concentration is calculated based on the relationship of CO concentration with the exposure time at each measurement location.

![Figure 9. Percentage of CO reductions in the day time.](image)

Figure 9 shows the percentage of CO reduction in the day time that is caused by the influenced of predominant wind direction toward receptor positions. CO concentration will decrease 17% if predominant wind direction form angle 45° to the receptor position and then CO reduced by 31% for angle 90° between receptor position and predominant wind direction.
Reduction of CO concentration is also occurred at the night time condition. It can be seen in Figure 10 that in the 45º angle receptor position, CO concentration will be decrease 10% than in the predominant wind direction. Meanwhile the 90º angle position between receptor position and predominant wind direction will reduce 20% of CO concentration.

The reduction of CO concentration that caused by the position of receptor position toward predominant wind direction is shown in Figure 10.

4. Conclusion
The CO concentration received by the receptor is affected by wind direction. The highest CO concentration is received by receptors in the downwind position of predominant wind direction. For all the day, CO concentration decreases by 13.79% at 45 degrees from the dominant wind direction and decreases by 25.38% in a position perpendicular to the dominant wind direction.

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