# Air Pollution Modelling For Carbon Monoxide and Total Particle From Coal-Fired Power Plant Activity

Muhaimin[1*], Eko Sugiharto[2], Adhitasari Suratman[2]

[1]Department of Chemistry Education, Mathematics and Natural Science Faculty, Islamic University of Indonesia, Yogyakarta,
[2]Chemistry Department, Mathematics and Natural Science, Gadjah Mada University, Yogyakarta
*email: el.muhaimin@gmail.com

**Abstract**

Air Pollution Modeling from coal-fired power plant activity include carbon monoxide and total particle ware modeled using gaussian plume equation. This research has involved meteorology and enviromental monitoring secunder date. They have been taken from Cirebon Coal Fired Power Plant for 1 year. The gases pollutant dispersion modeling has been done using Gaussian Plume Model. The result showed that pollutant gas for carbon monoxide and total particle were not exceeding the Threshold Limit Value permitted by the government regulation.

**Keywords:** *gaussian plume, coal fired power plant, carbon monoxide, total particle*

## Introduction

Carbon monoxide (CO) is one of the most air pollutants in the air (Mohammed, 2009). The process of complete combustion of any fuel containing carbon produces carbon dioxide ($CO_2$). Carbon monoxide (CO) is a poisonous gas and at a certain concentration can be harmful to human health (Coll, 2002). The process of methane oxidation is a major source of CO, such as the fuel combustion process in an industry. Two-thirds of CO produced is the result of human activity (Seinfeld and Pandis, 2006). CO and $CO_2$ are carbon oxides main cause of air pollution from the combustion process (Nesaratnam and Taherzadeh, 2014).

CO is a odorless, colorless and toxic gas. It can cause mild flu-like effects. Other symptoms caused by CO are headaches, dizziness, disorientation, nausea and fatigue. The effects of CO exposure vary from each person, depending on age, overall health depends on the concentration and duration of exposure (Kumar, 2010).

Then, the pollutants are released by power plants in addition to carbon monoxide is the total particle. It is a term used to describe materials that are solid and liquid in the atmosphere. The shape of each particle in the atmosphere varies from the size, geometry, mass, concentration, chemical composition and physical properties (Kumar, 2010).

The particle can be dangerous to humans because it can interfere with the breathing process if inhaled. The respiratory system can be demaged by particles if they are inhaled through the capillary channel lungs and alveoli. Then, the particles in the body system will slow down the process of exchange between oxygen and carbon dioxide in the blood and can cause shortness of breath. These particles are smaller than 4 μm, while particles with sizes greater than 4 μm will be trapped in the upper respiratory system like nose (Mohammed, 2009).

The emissions from power plant's stack will be dispersed by air. One model that can be used to predict the pattern of dispersion of pollutants in the air is gaussian plume model. The model is an approach used to study the pollutant in the air due to the turbulent diffusion and advection due to wind (Stockie, 2011). It is the main method used to calculate the concentration of pollutants from a point source such as power plant's stack. This model can be used in environmental impact assessment and design of the stack.

The concentration of pollutants in the modeling is largely determined by meteorological parameters such as wind speed, ambient temperature and distribution Pasquill Class (distribution of atmospheric conditions in a year) which is used to determine a coefficient that is needed in the analysis of the calculations,it is also determined by the characteristics of the plant in the form of physical parameters stack (Mayasari, 2012).

Gaussian plume models are often used to predict the dispersion of pollutants continuously emanating from the surface or plateau. It is assumed that the dispersion of pollutants have a gaussian distribution or have a normal probability distribution. This model assumes that the atmosphere has a stagnant state, homogeneous and the concentration of pollutants will be normally distributed. Input for this model is very simple which include wind speed, wind direction, distance from the source and pollutant dispersion coefficient σy and σz (Ukaigwe et al., 2013). The Gaussian plume equation can be defined as follow (Weiner and Matthews, 2003):

$$C_{(x,y,z)} = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left(\exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right)\right) \qquad (1)$$

where:

$C_{(x,y,z)}$ : the concentration at some point in space with coordinates x, y, z, and (g/m$^3$)

Q : the emission rate of the pollution source (in ds),

U : the average wind speed in (ds),

$\sigma_y$ : the standard deviation of the plume in the y direction (m), and

$\sigma_z$ : the standard deviation of the plume in the z direction (m).

Particles small enough to stay in the air for appreciable periods of time are dispersed in the air, but in a slightly different way than gaseous pollutants are dispersed. The dispersion

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equation must be modified by considering the settling velocity of these small particles. The settling velocity follows Stokes' law. The equation can be express as follow:

$$v_t = g \times d^2 \frac{\rho}{18\mu} \quad (2)$$

where,

$v_t$ : Settling velocity
g : Gravity force
d : Particle diameter
$\rho$ : Particle density
$\mu$ : Air viscosity

Then, for particle dispersion equation according to gaussian plume model can be defined as follow:

$$C(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \times \left(\exp\left(-\frac{\left(z+H-\frac{v_t x}{u}\right)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{\left(z-H-\frac{v_t x}{u}\right)^2}{2\sigma_z^2}\right)\right) \quad (3)$$

**Methods**

The location of the research was centered around the Cirebon power plant, in which the dispersion of pollutants maximum distance of 20,000 meters. The research has involved secondary date. They were the environmental monitoring data and climate secondary data. they have been taken from Cirebon power plant for the last one year (October 2013 to September 2014). Meteorological data ware used to determine the wind direction. Then, the environmental monitoring data has been processed using Gaussian plume equation to determine the dispersion and concentration of pollutants in the air.

**Results and Discussion**

**Wind Direction into Ambien Air**

Pollutants in the air will be dispersed because of the gusts of wind in the air, as well as the direction of the pollutant also follow the pattern of the wind direction. To determine the wind direction during the dry and the rainy season, meteorological data was processed by using WRPLOT software. Figure 1 presented wind rose in rainy and dry season.

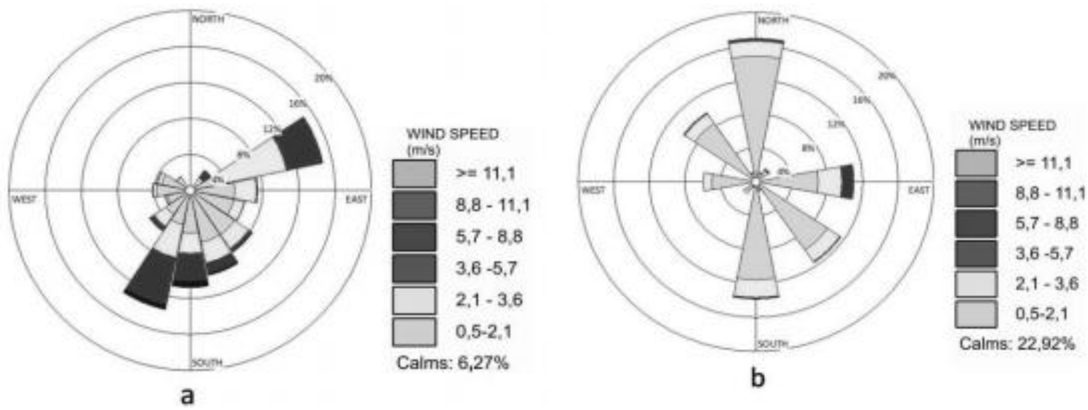


Figure 1. Wind rose in rainy (a) and dry (b) season

In rainy season, the dominant wind direction was blowing from southwest toward the northeast with the average speed of 2.05 m/s. Then, in the dry season, the dominant wind direction was blowing from south to north at the average speed of 1.21 m/s.

**Dipersion Modeling of Carbon Monoxide**

Carbon Monoxide is the result of coal combustion process, in which the coal combustion process requires oxygen supplied from the air. Then it is in the air will react with oxygen to form carbon dioxide ($CO_2$).

$$2C + O_2 \longrightarrow 2CO \qquad 4$$

$$2CO + O_2 \longrightarrow 2CO_2 \qquad 5$$

In the modeling, the rate of emission (Q) used in the rainy season is 0.492 g / s, while the emission rate (Q) in the dry season is 0,425 g/s. The Modeling results pollutants of CO in the rainy and dry seasons was showed in Figure 1 and 2.

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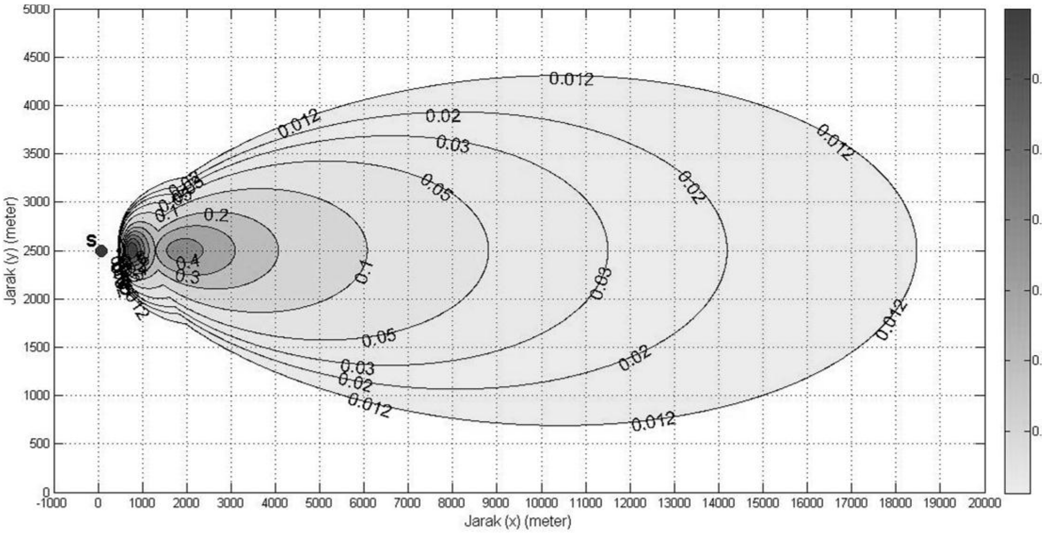


Figure 2. Dispersion of Carbon monoxide in rainy season

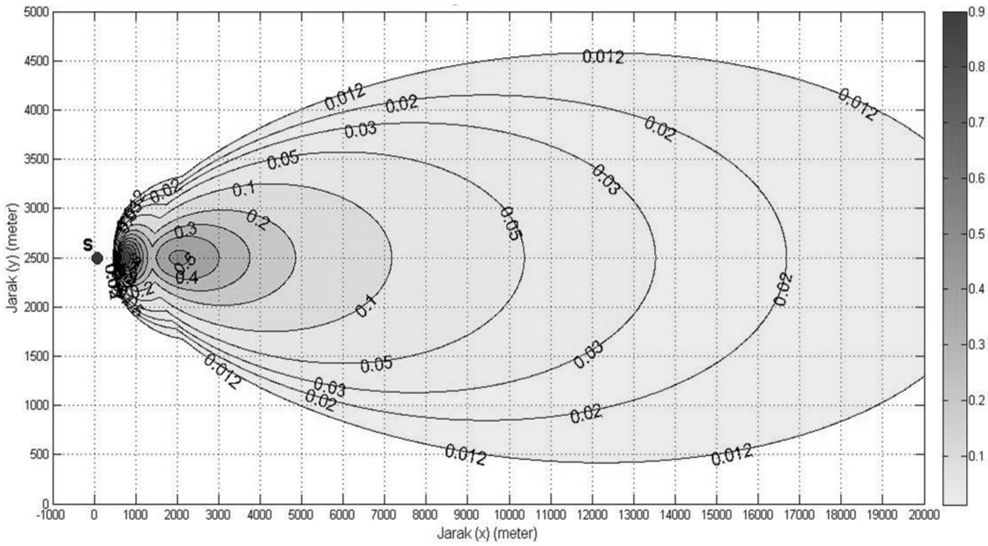


Figure 3. Dispersion of Carbon monoxide in dry season

Figure 2 and 3 showed the maximum concentration of pollutants CO between rainy and dry seasons. In the rainy season, the maximum CO concentration is 0.79 µg/m$^3$, whereas in the dry season was 0.96 µg/m$^3$. Maximum concentration in the rainy season is at a distance of 740.741 m of the stack, while the dry season was at a distance of 780.781 m of stack. This difference may be due to the high water content. The water rains diluted the pollutants CO in the air. So, the concentration become lower than in the dry season.

The pollutant distribution pattern also shows the difference between rainy and dry seasons. In the dry season the distribution of pollutants wider scope to more than 20 km from the chimney at a concentration of 0.012 µg/m$^3$, while in the rainy season, with the same concentration in the dry season, the distribution range of pollutants CO less than 20 km or about 18.5 km of the stack.

According to the figure, the differences in color on every specified distance indicates the level of concentration differences, black color indicates that the highest concentration of pollutants, then to white color indicates that the lowest concentration of the pollutants. When viewed on a color bar that was located on the right of the graph, it showed the downward then the value will decrease in line with the change of color from magenta to yellow

**Dispersion Modeling of Total Particle**

The emission rate which was used for modeling of total particles dispersion in the rainy season was 0.726 µg/m$^3$, while the emission rate for the dry season amounted to 0.308 µg/m$^3$. Total particle dispersion modeling results with gaussian plume models showed in Figure 4 and 5. The Modeling results pollutants of total particle in the rainy and dry seasons was showed in Figure 4 and 5.

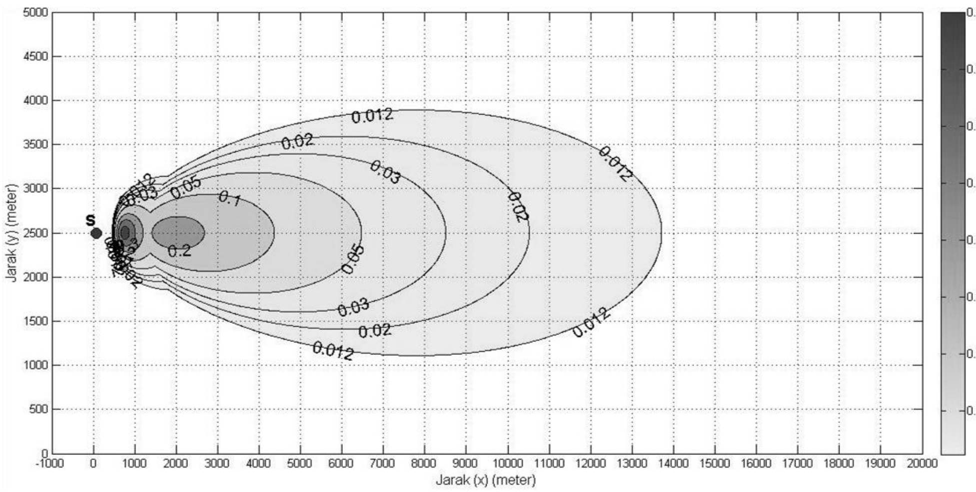


Figure 4. Dispersion of total particle in rainy season

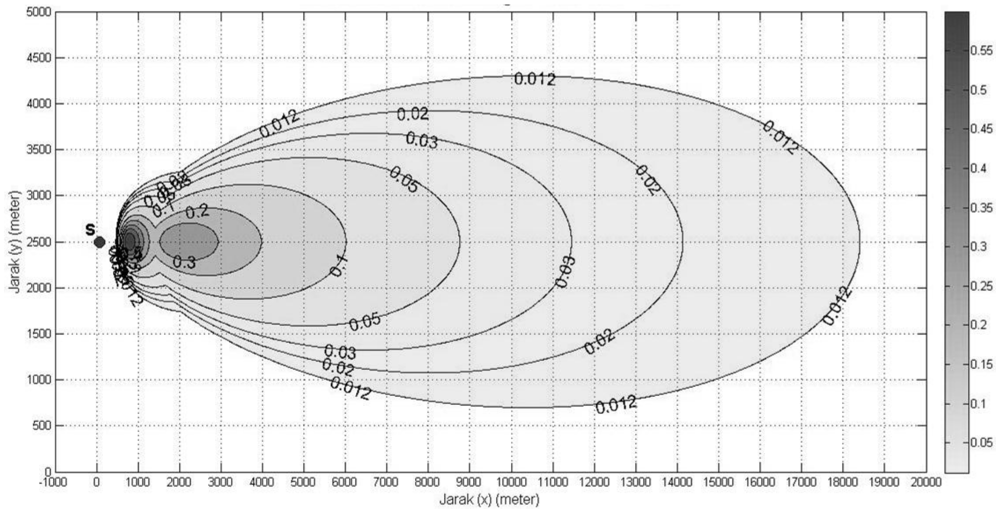


Figure 5. Dispersion of total particle in dry season

Based on Figure 4 and 5 showed that the maximum concentration of total particles in the ambient air in the rainy season occured at a distance of around 740.741 m of stack that the direction of the axis x with the concentration range of 0.45 µg/m$^3$. Whereas in the dry season, the maximum concentration of total particles at a distance of around 780.781 m of stack that the direction of the x axis.

In the rainy season, the lowest concentration of total particles was showed in Figure 4 and located at a distance of about 13.73 km from the chimney at a concentration of 0.012 µg/m$^3$. The distance is lower than in the dry season that equaled to 18.42 km with the same concentration. So, the total particles in the dry season was more dispersed than during the rainy season. Bhaskar and Mehta (2010) stated that during the rainy season, the pollutant particles would experience the washing process in the atmosphere by rain water. Rainy deposition during the rainy season resulted in the concentration of particles in the atmosphere decreases. The deposition process was one of the main mechanisms for removing particles in ambient air. In addition to the wind speed, the dispersion of pollutants can also be influenced by gas temperature, flow rate of gas coming out of the stack.

**Study of Impact Assessment of Air Pollution from Coal Fired Power Plant**

The impact Assessment of air quality in this study was conducted to determine the region/receptor that was affected by the coal fired power plant activities with comparing the modeling results with ambient air quality standards based on threshold limit value permitted by the government regulation number 41 in 1999. The results of modeling the dispersion of pollutants in the rainy season and dry was presented in Table 1.

Tabel 1. Results of Pollutants Dispersion Modeling in The Rainy And Dry Season

| Season | Distance (m) | [CO] (µg/$m^3$) | Quality standards* | Distance (m) | [TP] (µg/$m^3$) | Quality standards* |
|---|---|---|---|---|---|---|
| rainy | 760,761 | 0,79 | 30.000 µg/$m^3$ | 760,76 | 0,45 | 150 µg/$m^3$ |
| | 18.500 | 0,012 | | 13.730 | 0,012 | |
| dry | 780,781 | 0,96 | | 780,78 | 0,70 | |
| | >20.000 | 0,012 | | 18.420 | 0,012 | |

*) threshold limit value permitted by the government regulation number 41 in 1999

According to Tabel 1. The pollutants concentration in the ambient air was still in the stage of tolerance, because the pollutants concentration value was very small. The result of modeling showed that pollutant for carbon monoxide and total particle on residential location around the coal fired power plant were not exceeding the threshold limit value permitted by the government regulation number 41 in 1999.

## Conclusion

The dispersion modeling results for carbon monoxide and total particle from Cirebon coal-fired power plant activity were not exceeding the threshold limit value permitted by the government regulation number 41 in 1999.

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