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2017 J. Phys.: Conf. Ser. 795 012072

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Air Pollution Simulation based on different seasons

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Abstract. Simulation distribution of pollutants (SO_x and NO_x) emitted from Cirebon power plant activities have been carried out. Gaussian models and scenarios are used to predict the concentration of pollutant gasses. The purposes of this study were to determine the distribution of the flue gas from the power plant activity and differences pollutant gas concentrations in the wet and dry seasons. The result showed that the concentration of pollutant gasses in the dry season was higher than the wet season. The difference of pollutant concentration because of wind speed, gas flow rate, and temperature of the gas that flows out of the chimney. The maximum concentration of pollutant gasses in wet season for SO_x is 30.14 µg/m³, while NO_x is 26.35 µg/m³. Then, The simulation of air pollution in the dry season for SO_x is 42.38 µg/m³, while NO_x is 34.78 µg/m³.

1. Introduction

Qualitative aspects of the theory of dispersion of pollutants in the air is to describe the state of emissions in the atmosphere from pollution sources which in assumed to be point source. Qualitatively, this dispersion theory can approximate pollutants concentration in the ambient air, one of the models of dispersion of pollutants in the air are Gaussian Plume [1]. Gaussian Plume Model is an approach used to study the contaminants in the air because of the turbulent diffusion and advection caused by the wind [2]. Gaussian Plume Models are often used to predict the spread of continuous air pollution originating from the surface or plateau. It is assumed that the spread of air pollution has a gaussian distribution or have a normal probability distribution. This model assumes that the atmosphere had a stagnant and homogenous state, the concentration of pollutants will be distributed normally. Input for this model is very simple which include wind speed, distance distribution of pollutant gasses from sources and distribution coefficient of pollutant gasses [3]. The equations of the model for the Gaussian Plume dispersion of pollutants in the air can be expressed as follows [4]:

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

where,

$C(x, y, z)$: Gas concentration in x,y,z coordinate (g/m³),

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Q	: Gas emission rates from (g/s),
U	: Wind speed average (m/s),
σ_y	: Plume standard deviation in line with y-axis (m),
σ_z	: Plume standard deviation in line with z-axis (m),
H	: Effective stack height (m)

The Gaussian Model is the most mathematical model to predict air pollution dispersion. It is widely used, easy to be understood and applied, and the assumption of the model that the air pollutant will be dispersed based on the normal statistical distribution [5,6]. Dispersion simulation uses equation to predict the concentration of air pollutant that emitted by a point source. Meteorology and emissions data are used to predict the dispersion of pollutants in the atmosphere [7,8].

The purposes of this study were to determine the distribution of the flue gas from the power plant activity, differences of pollutant gas concentrations in the wet and dry seasons.

2. Experimental methods

Parameters of air pollution in this research were SO_x and NO_x . In Indonesia has two seasons, they are the dry season (April - September) and the wet seasons (October - March). In this paper will discuss the simulation of air pollution based on the different season. This research used quantitative analysis method using Gaussian Plume equation. The data used in this study is secondary data. The secondary data on climatology used was in year 2012-2013. Then, the data of pollutant gas was taken from Cirebon Coal Fired Power Plant. The distance dispersion of pollutants was observed in this research is in line with the x-axis of the sources of pollutants (chimney) is 20,000 meters, while the distance is in line with the y-axis is 1,500 meters.

3. Results and Discussion

To determine the direction of dispersion of pollutants in the air as a result of the activity of the power plant, modeling the wind direction is done by using data of wind speed and direction obtained from air monitoring of Cirebon power plant in West Java, during one year from October 2012 until September 2013 using WRPLOT. In the wet season, the dominant wind direction was blowing from Northeast and southwest at speeds ranging from 2,05 m/s, shown in Figure 1(a). Then, in the dry season showed that the dominant wind direction was blowing from north and south at speeds ranging from 1,21 m/s, shown in Figure 1(b).

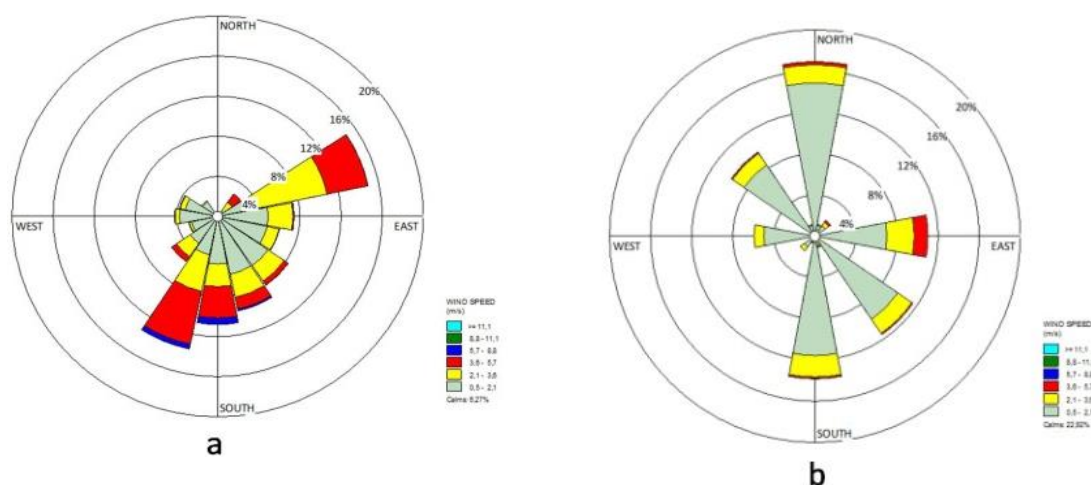


Figure 1. The wind rose in the wet season (a) and the dry season (b)

The simulation results of gas dispersion of pollutants into the atmosphere was done by using Gaussian Plume equation taking into account with the meteorological and environmental monitoring data which conducted by Cirebon power plant. They have been carried out in April 2012 to March 2013. The specification of secondary data used in the simulation of pollutant dispersion around Cirebon power plant is shown in Table 1.

Tabel 1. The Secondary Data Used in Simulation

Parameter	Value		Unit
Inside Diameter of Stack	6,85		m
Physical Stack Height	215		m
	Dry Season	Wet Season	
Stack Gas Exit Temperature	406.407	404.822	K
Temperature of Ambient Air	302.410	301.221	K
Stack Gas Exit Velocity	0.165	0.207	m/s
Wind Speed	1.235	1.958	m/s
Emission Rate:			
• SO _x	18.713	18.683	g/s
• NO _x	15.356	16.331	g/s
Distance Distribution Of Pollutant Gasses	100 - 20000		m

3.1. Dispersion model of SO_x

Combustion of fuels containing sulfur, such as coal and oil are used as fuel in power plant such that resulted sulfur dioxide (SO₂). It can cause health problems in humans and the environment [9,10] and react to the other chemical in the ambient air to create sulfate particles [14]. The sulfur compounds formed in the atmosphere are two kinds of SO₂ and SO₃, both called by SO_x and from the burning of fossil fuels around 75% of the total amount of emissions of SO_x [13].

Figure 2 showed that the maximum concentration of SO_x in the dry season was 42.38 µg/m³ (about 780.78 meters from the source in the direction of the x-axis), while the wet season is 30.14 µg/m³ (about 740.74 meters from the source direction of the axis x). In the region, there are no settlements, only rice fields. The difference is caused by the concentration factor of water present in the atmosphere, the water content in the rainy season will be higher than in the dry season.

The high rainfall during the wet season will dissolve compounds of pollutants in ambient air so that it will experience wet deposition. So that the wet deposition can lower the concentration of pollutants in ambient air, or in other words, the presence of rainwater, pollutants in the atmosphere will experience a dilution that resulted in a decrease in the concentration of pollutants [16].

The removal of SO₂ in the atmosphere at a wet deposition process is influenced by some factors namely rainfall, the length of the rain, frequency of rain, and the relative amounts of SO₂ and sulfate particle size distribution [11].

In the dry season does not happen sulfate dilution process to pollutants in ambient air, because the water content in the atmosphere is less common than in the wet season. High sulfate concentrations indicate that oxidation and changing of SO₂ to sulfate rely on the reaction of photochemical oxidation, the sulfate concentration in the day is higher than at night, this is caused by the presence of sunlight [12]

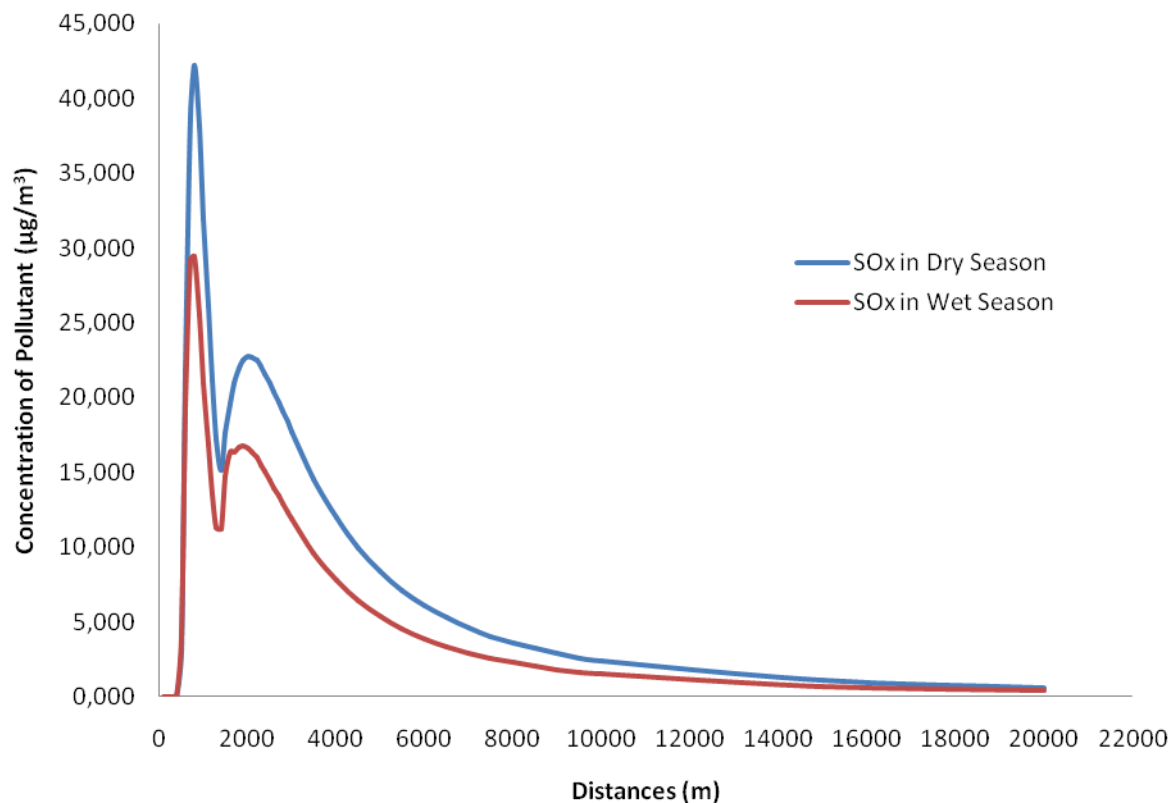


Figure 2. Dispersion of pollutant SO_x in the wet and the dry seasons.

3.2. Dispersion model of NO_x

NO_x is a definition used to explain the amount of nitrogen oxide (NO), Nitrogen Dioxide (NO_2), and nitrogen oxides, and several others. It is a pollutant that can result if the acid rain reacts with volatile organic compounds through complex reactions, assisted by sunlight and water vapor in the atmosphere. The main source of NO_x emissions derived from the activities of electricity generation and motor vehicles [14]. The impact of NO_x gasses are: increasing the concentration of ozone, cause respiratory disease and cancer in humans, increasing global climate change, reducing agricultural productivity result from the deposition of ozone, and decrease biodiversity ecosystems [13].

One of the efforts to control NO_x concentrations in ambient air is the air dispersion modeling. According to the Figure 3 showed that the maximum concentration of NO_x in the wet season is at $26.35 \mu\text{g}/\text{m}^3$ which is located at a distance of 740.741 meters from the source (chimney). Whereas in the dry season, the maximum concentration of NO_x was $34.78 \mu\text{g}/\text{m}^3$ at a distance of 780.781 meters from the source (chimney). This difference can be caused by ambient air temperature, wind speed, rainfall, and others. In the dry season more diffuse plume of NO_x distributed than in the dry season, it can be seen from the reach of the lowest concentration that are at different distances. NO_x concentration of the lowest in the wet season is at a maximum distance of about 18 km while the dry season is at a distance of over 20 km.

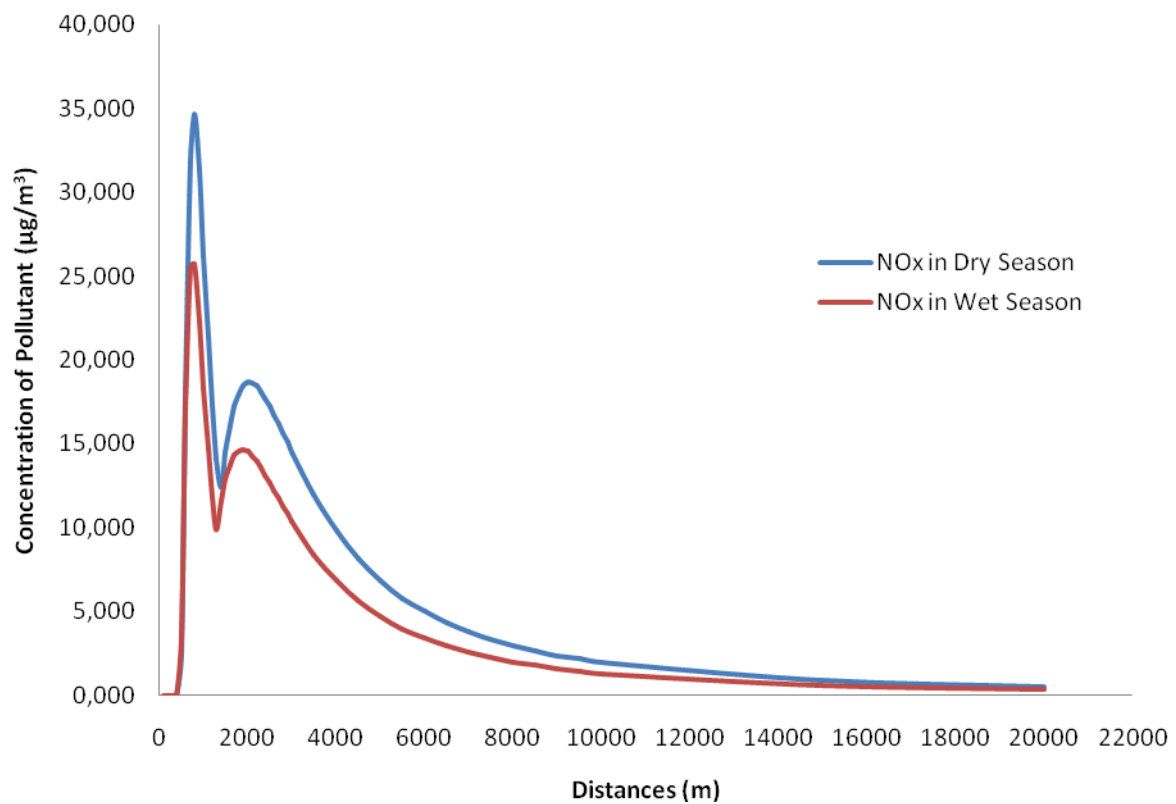


Figure 3. Dispersion of pollutants NO_x in the wet and the dry seasons.

As well as SO_x , NO_x in the atmosphere will also experience deposition both wet and dry deposition. In the wet season NO_x will experience wet deposition, whereas in the dry season NO_x pollutants will experience dry deposition. In the process of wet deposition compound ammonium (NH_4^+), nitrate (NO_3) will be up to the surface through rain water, while in the dry deposition of nitrogen compounds will eliminate gasses NH_3 , NO_2 , HNO_3 (with particles NH_4^+ , NO_3 , organic compounds), organic acids, and aerosols containing nitrogen. Release of NO_x compounds from the combustion reaction is a major component in the formation of nitrogen oxides (NO). Zeldovich reaction showed that the nitrogen oxide (NO) is generated from the oxygen supply of free air around 200,000 ppm in the atmosphere at temperatures above 1300°C . at a temperature below 760°C , Concentration of NO compounds is very low even not be produced [13]. NO production is a function of the fuel to air ratio [15]. The distribution of pollutant gasses SO_x and NO_x in the dry and the wet season are shown in Figure 4.

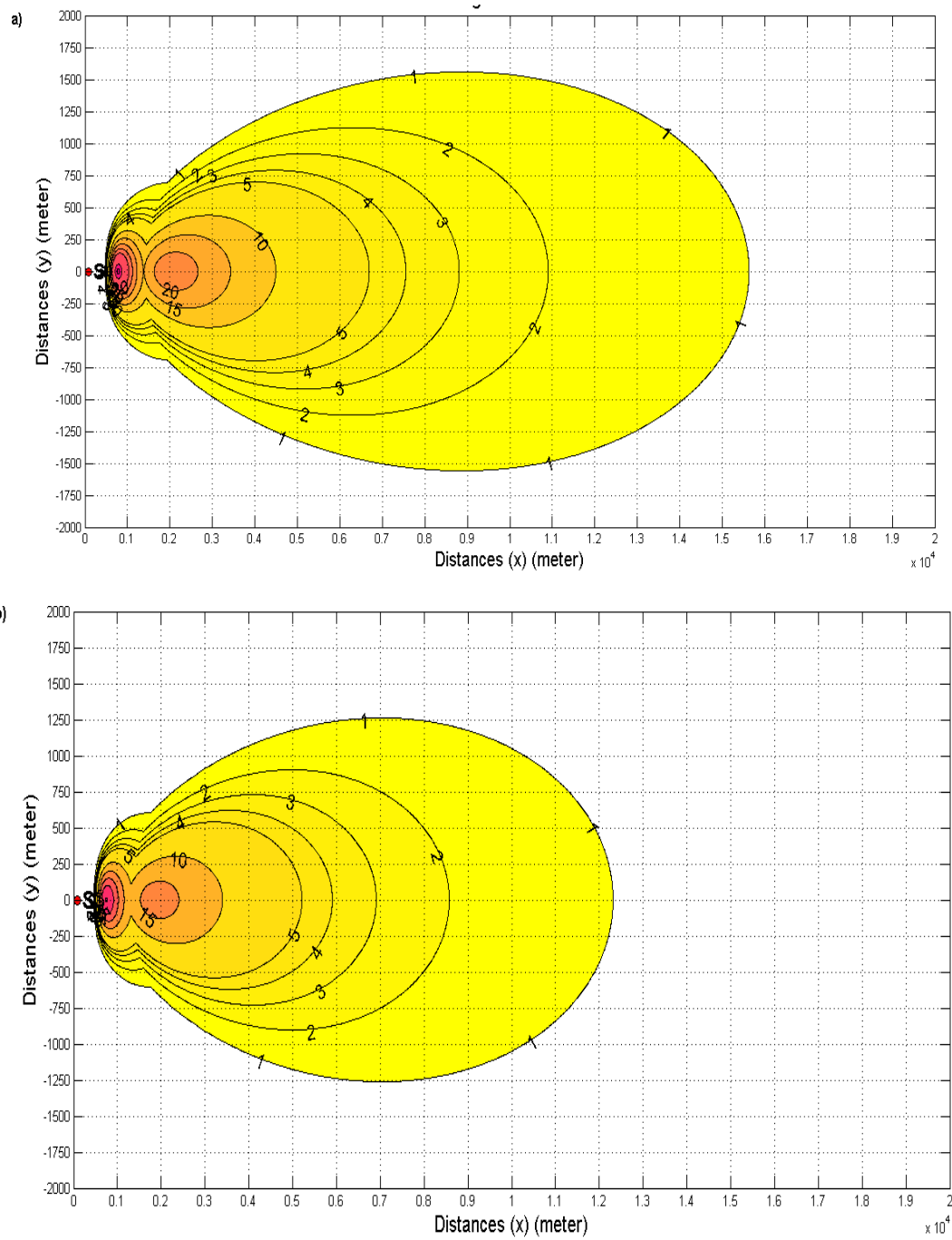


Figure 4.a Distribution Of Pollutant Gasses SO_x in The Dry Season (a) And The Wet Season (b)

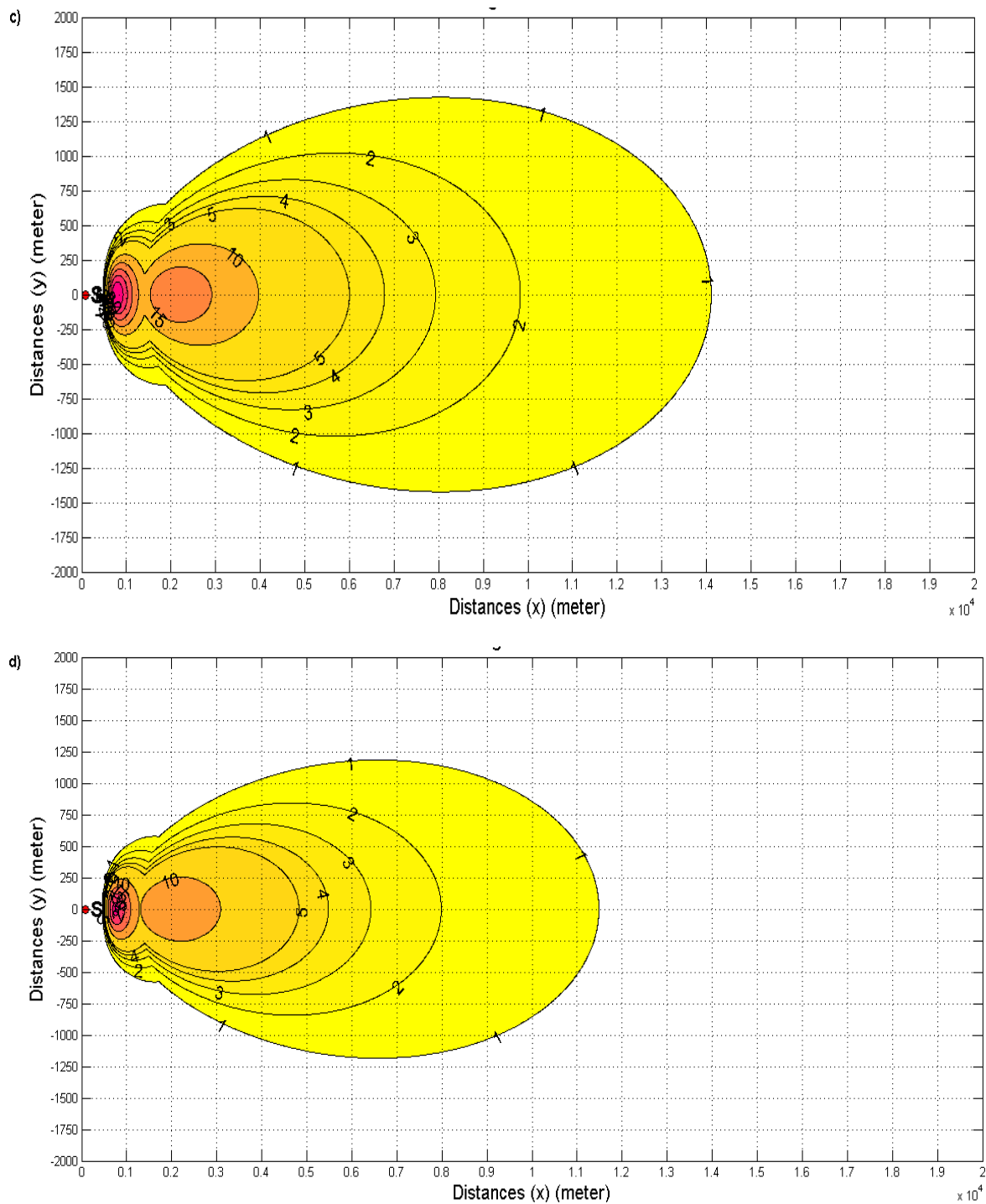


Figure 4.b Distribution Of Pollutant Gasses NO_x in The Dry Season (c) And The Wet Season (d)

4. Conclusion

In conclusion, the concentration of pollutant gasses in the dry season was higher than during the wet season. The maximum concentration of pollutant gasses in wet season for SO_x is $30.14 \mu g/m^3$, while NO_x is $26.35 \mu g/m^3$. Then, The simulation of air pollution in dry season for SO_x is $42.38 \mu g/m^3$, while NO_x is $34.78 \mu g/m^3$.

Acknowledgment

Thankful is acknowledged to PLTU Cirebon and PSLH UGM as partner research.

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