SIMULATION OF POLLUTANT GAS DISPERSION ON CASE STUDY OF *LONTAR 3* COAL FIRED POWER PLANT IN ADDITION INTO 1 x 660 MW CAPACITY IN KEMIRI, TANGERANG DISTRICT, BANTEN PROVINCE

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ABSTRACT

Air quality simulation has been performed for additional capacity of Banten 1 x 600 MW Coal Fired Power Plant toward air quality degradation in its surrounding environment. The simulation was based on pollutant gas dispersion calculated using Gaussian Plume equation. The research has involved climate secondary data on Cengkareng climatology Station for last 10 years. Besides, the primary data has also been taken in 7 point sampling locations to determine initial ambient air quality of existing 1 x 600 MW Coal Fired Power Plant. The data of existing 1 x 600 MW coal fired power plant has been taken from Adipala Steam Power Plant while the gas pollutant dispersion simulation has been done well using Gaussian Plume equation. The result showed that gas emission for NO_2, and TSP parameter in all scenarios and SO_2 gas parameter in several scenarios were exceeding the Threshold Limit Value. Thus, a technology is needed to minimize produced emission gas. The increase of gas pollutant in all sampling locations was not significantly increasing and those gas pollutants were not generally exceeding the threshold limit value permitted by the government regulation.

Keywords: *dispersion; Gaussian Plume; Coal Fired Power Plant*

ABSTRAK

Telah dilakukan penelitian simulasi kualitas udara untuk Penambahan Kapasitas PLTU Banten 1 x 600 MW terhadap penurunan kualitas udara di lingkungan sekitar. Simulasi didasarkan pada dispersi gas polutan yang dihitung dengan menggunakan persamaan Gaussian Plume. Penelitian dilakukan dengan mengambil data sekunder iklim di Stasiun Klimatologi Cengkareng selama 10 tahun. Selain itu pengambilan data primer juga dilakukan di 7 lokasi untuk menentukan kualitas udara awal sebelum penambahan kapasitas 1 x 600 MW berlaku. Data PLTU 1 x 600 MW diperoleh dari PLTU Adipala, dan simulasi dispersi gas polutan dilakukan dengan menggunakan persamaan Gaussian Plume. Hasil penelitian menunjukkan bahwa emisi gas buang untuk parameter NO_2, dan TSP untuk berbagai skenario dan sebagian skenario untuk gas SO_2 melebihi baku mutu emisi yang telah ditetapkan, sehingga diperlukan teknologi untuk mengurangi emisi gas yang dihasilkan. Peningkatan gas polutan di seluruh lokasi pengambilan sampel tidak mengalami peningkatan secara signifikan dan konsentrasi gas polutan masih dibawah baku mutu udara ambient yang ditetapkan oleh pemerintah

Kata Kunci: *dispersi; Gaussian Plume; PLTU*

INTRODUCTION

Economic growth and development process in Indonesia has increased significantly so that there is no doubt that increased consumption of energy is the primary requirement to be fulfilled to enhance national development. The World Bank noted Indonesia requires fossil energy as basic needs that increases 86% year by year from the total electricity needs by 2011 [1]. Electricity needs from renewable sources is only 14% i.e. Water Power Plant, Geothermal Power Plant, Solar Power Plant, and Wind Power Plant [2].

One of the fulfillments for electricity demand in Indonesia is produced by Coal Fired Power Plant with 48.6% of the total power generation in Indonesia and 42.4% of the total power plant using coal as its fuel [2]. Increasing pollution levels due to rapid industrialization and urbanization are now causes of major concern in industrializing countries [3]. Coal combustion for power generation and residential heating is believed to make

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the most important contribution to atmospheric emissions [4]. The usage of power plant to meet energy necessity has also an impact for the environment such as exhaust emissions that can pollute the ambient air. The pollutant in the ambient air can contribute for atmospheric deposition. Atmospheric deposition is an important pathway for the input of nitrogen species to the watershed and water bodies [5]. Power generation emits various types of waste such as liquid waste, gas, and polluting emissions such as noise, heat emissions [6]. The major pollutants are gases and particulate matters, gases such as oxides of sulphur, nitrogen and carbon, ammonia and hydrocarbon [7]. United States Environmental Protection Agency (US EPA) states that power plants contribute air pollution because it produces pollutant gases such SO_2, NO_2, CO, and particle material [8]. By burning fuels in the thermal power stations, important quantities of polluting substances such as CO, CO_2, SO_2, NO_2, ash dust are emitted into the atmosphere that have a powerful impact on the environment factors [9]. The evaluation of the maximum concentration of air pollutants such as SO_2, NO_x, and suspended particulate matter is usually considered of primary importance for environmental impact assessment [10]. Analyses of the environmental effects arising from power plants using a variety of models suggest that air quality effects depend on a wide variety of local atmospheric parameters as well as on the combustion technology [11].

There are some methods to predict pollution in air environment such mathematical air pollution modeling. Mathematical air pollution modeling represents an essential tool to control and predict atmospheric pollution [12]. Gaussian plume can be used to determine pollutant dispersion in the environment [13-16]). Moreover, the Gaussian plume model is a standard approach for studying the transport of airborne contaminants due to turbulent diffusion and advection by the wind [17]. Gaussian equation can be expressed as follows:

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

where,

C(x,y,z) : Gas concentration in x,y,z coordinate (g/m^3),
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 y axis (m),
H : Effective stack height (m)

While pollutant dispersion for particle material can be predicted from the following equation:

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

$$v_t = g\times d^2\frac{\rho}{18\mu} \quad (3)$$

where,

v_t : Settling velocity
g : Gravity force
d : Particle diameter
ρ : Particle density
μ : Air viscosity

Pollutant concentrations on ambient air are important to be determined in connection with hazardous level to the people.

PT PLN (Persero) as a supplier of electric energy, has planned to added capacity for Coal Fired Power Plant in the Lontar region in order to meet energy necessity in Jakarta and its surrounding area by building new power plant with 1 x 660 MW capacity. The selected location is planned in Lontar village, Kemiri, Tangerang District, Banten Province. Besides, there is an existing power plant right now with of 3 x 315 MW capacities. The burning of coal as energy source for power plant will emit pollutant gases which will degrade the quality of ambient air thus it is necessary to study the impact occurred of air quality deterioration. This study will examine gas emissions and pollutant dispersion with a radius of 10 km from the various scenarios.

EXPERIMENTAL SECTION

Materials

Material used for the research were divided into 4 types of material for every samples i.e. SO_2, NO_2, CO and TSP parameters. List of materials were based on *Standar Nasional Indonesia* (SNI) or Indonesian National Standard as divided as SO_2 material (SNI 19-7119.7-2005) including Tetra Chloro Mercurate (TCM) 0.04 M, $Na_2S_2O_5$, I_2 0.1 N, starch Indicator, HCl, $Na_2S_2O_3$ 0.1N, NH_2SO_3H 0.6% b/v, H_3PO_4, and $C_{19}H_{17}N_3$.HCl 0.2% (18). For NO_2 material (SNI 19-7119.2-2005) such as $H_2NC_6H_4SO_3H$, CH_3COOH, Aquadest, $C_{12}H_{16}Cl_2N_2$, C_3H_6O, and NO_2 [19], while for CO material (SNI 19-4845-1998) including activated carbon, selected gel, H_2SO_4 and L_2O_5 crystal [20]. In addition, for TSP material (SNI 19-7119.3-2005), glass fiber filter, silica fiber filter and cellulose filter were used [21].

Instrumentation

Instrumentation used for the research were divided into 4 types of material for every samples i.e. SO_2, NO_2, CO and TSP parameters. List of instrumentations were based on *Standar Nasional Indonesia* (SNI) or Indonesian National Standard as

Fig 1. Location of Lontar Coal Fired Power Plant

Table 1. Modeling scenarios

No	Name	Concentration of coal	Excess air	Chimney total	Chimney diameter (m)	Pollutant
1	Case-1	390	-	Single (1)	6.7	SO_2, NO_2, CO, TSP
2	Case-2		-	Double (2)	5.2	
3	Case-3		10%	Single (1)	6.7	
4	Case-4		10%	Double (2)	5.2	

divided as SO_2 instrumentations (SNI 19-7119.7-2005) [18] as well as NO_2 instrumentations (SNI 19-7119.2-2005) with UV-Vis Spectrophotometer [19], while CO instrumentations (SNI 19-4845-1998) with Non Dispersive Infra Red (NDIR) [20] and for TSP instrumentations (SNI 19-7119.3-2005) High Volume Air Sampler (HVAS) was used [21].

Procedure

Research location of Lontar power plant carried out in Lontar village, Kemiri, Tangerang District, Banten Province (Fig. 1). It was about 20 miles from Cengkareng, Tangerang. The meteorological data was taken in Cengkareng Climatology Station. Meteorological data used were wind speed, wind direction, and temperature for last 10 years.

The scenario used in this modeling was to calculate the load consumption of coal used and its accompanying air mass thus it would be obtained flow rate in the chimney for each dimension of chimney that will be used. Air mass necessity was calculated as stoichiometric (theoretical) of the composition of element content in coal with oxygen necessity in the air. The air mass for each weight of coal used was determined by the composition of the coal used, where was calculated by equation [9]:

$$U_{og} = 11.5\ C + 34.5\left(H - \frac{O}{8}\right) + 4.325 \qquad U_{ov} = \frac{U_L}{1.29} \tag{4}$$

where,
U_{og} = Theoretical air necessity (kg_{air}/kg_{coal})
U_{ov} = Theoretical air necessity ($m^3{}_{air}/kg_{coal}$)
C,H,O and S = C,H,O and S fraction on each kg of coal (%)

The study was done by modeling some parameters to get a massive amount of emissions and pollutants dispersion of gaseous pollutants in the ambient air in the study area. Its summary can be seen in Table 1.

Air quality samplings were conducted for 24 h for SO_2, NO_2, CO and TSP parameters in 7 residential locations closest to Lontar Power Plant. The analysis of gases was performed using pararosaniline method for SO_2, Gries Saltzman for NO_2, NDIR method for CO, and the gravimetric method using high volume air samplers

Table 2. Emission factor for gas emission of coal fired power plant using bituminous and subbituminous coal

Parameter	Coal emission factor (lb/ton)
SO_2	38 S
NO_2	22
NOx (with low NOx Burner)	11
CO	0.5
PM (TSP)	10 A
PM-10	2.3 A
PM-2,5 (uncontrol)	0.6 A
PM-2,5 (ESP)	0.024 A

Source: US EPA, 1993 (with A = Coal Ash Content and S = Coal Sulphur Content)

Table 3. Typical coal specification

No	Parameter	Unit	Amount
1	Coal necessity	ton	349.4
2	Calorific value (HHV)	k.Cal/kg	4200
3	Coal contents		
	a. Ash content	%	5
	b. Sulphur content (daf)	%	0.4
	c. Carbon	%	68.57
	d. Hydrogen	%	5.16
	e. Nitrogen	%	1.18
	f. Oxygen	%	24.76

Table 4. Pollutant flow rate

Parameter	Value		Unit
Excess air	0	10%	
Chimney diameter			
Uog	8.61	9.47	kg air/kg coal
Air necessity /kg coal	8.61	9.47	kg/s
Total air necessity	933.31	1026.65	kg/s
Air necessity + coal	1041.65	1134.98	kg/m^3
Flow rate			
Single stack (stack diameter 6.7 m)	34.34	37.41	m/s
Double stack (stack diameter 5.2)	28.50	31.05	m/s

Table 5. Emission result based on coal consumption load

No	Name	Pollutant concentration (mg/Nm^3)[1]			
		SO_2	NO_2	CO	TSP
1	Case-1	*808.01*	*1169.49*	26.57	*2657.93*
2	Case-2	*808.01*	*1169.49*	26.57	*2657.93*
3	Case-3	741.56	*1073.32*	24.39	*2439.37*
4	Case-4	741.56	*1073.32*	24.39	*2439.37*
Threshold Limit Value (TLV)		750	750		100

Note: [1)] italic fonts indicated the value are excess the TLV. The operational condition for the calculation were at 25 °C and 1 atm; [2)] Environment Ministry Regulation No. 21 / 2008

for TSP. The amount determination for emissions from Coal Fired Power Plant 1 x 660 MW Expansion the combustion was based on emission factors developed by the U.S. EPA as presented in Table 2. Dispersion modeling of pollutants from the chimney into the ambient air was using gas outlet temperature at 120 °C in accordance with the data obtained from the Adipala power plant while the ambient air temperature was using room temperature. The chimney diameter was obtained using fluid dynamics calculations on which considered as the most effective method. Pollutant dispersion modelling was calculated using the Matlab software ver. 7.8.0.

RESULT AND DISCUSSION

Emission on Chimney

The coal combustion carried out to gain energy for driving the turbine will generate pollutant gas such as SO_x gases from sulfur contained in coal and will produce NO_x gases as nitrogen content in coal as well as the N_2 from the air used. An imperfect combustion will result carbon monoxide (CO) while the coal combustion process will result fine particles suspended in the air which will also be dispersed to the surrounding environment.

Emission calculation of coal combustion emissions for power plants was done by taking into account the type of coal used, the combustion process as well as the use of certain technologies that can reduce emissions levels. US EPA has conducted a review of the emissions resulting from the combustion process thus it issued emission factor for each fuel type and accompanying processes. Based on the calculations result, it was obtained pollution emission for modeling scenario using coal consumption as much as 390 tons/h and typical coal specifications are presented in Table 3.

Emissions calculations based on coal consumption load and the amount of air would affect the pollutants flow rate into the air. Based on the calculation, the type of typical coal will be generated emissions flow rate for each scenario as presented in Table 4.

Pollutants flow rate generated in Table 4 were used to calculate how many pollutants were removed by power plant based on its criteria scenario. The results of pollutant emissions for each scenario were presented in Table 5. Some pollutant parameters were still above the standard emission. SO_2 parameters exceed the standard emission on scenario 1 and 2 while it has met standard emission on scenarios 3 and 4 by adding the volume of air that was used as much as 10%. It would be better if SO_2 reducer tools such as

Table 6. Analysis result for ambient air quality on location

Code	Location	Coordinate	Parameter (μg/Nm^3)				Note
			SO_2	NO_2	CO	TSP	
R1	North Western site Tapak. Gaga Kiniar Village	S=06°03.554’ E=106°26.747’	49.80	2.77	37.02	124.69	T=32.0 °C Weather: Bright
R2	Kayu Apus Village	S=06°05.550’ E=106°27.415’	258.09	20.15	426.94	42.87	T=32.5 °C Weather: Bright
R3	South Western site. Gaga Ilir Village	S=06°04.689’ E=106°26.499’	3.09	15.27	2.97	129.01	T=32.4 °C Weather: Bright
R4	Western site. Gaga Kiniar Village	S=06°03.805’ E=106°26.962’	22.78	10.80	186.41	39.11	T=34.5 °C Weather: Bright
R5	South Western site. Gaga Tengah Village	S=06°04.106’ E=106°26.775’	278.02	24.71	523.30	125.49	T=35.0 °C Weather: Bright
R6	Southern Site. Biawakan Jaya Village	S=06°05.402’ E=106°26.996’	115.60	44.01	908.70	27.78	T=29.4 °C Weather: Bright
R7	Site. In front of Baitun Nur Mosque	S=06°03.604’ E=106°27.734’	65.32	9.41	126.17	45.51	T=31.8 °C Weather: Bright
	Threshold Limit Value		365	150	10.000	230	Environment Ministry
	Sampling Time		24 h	24 h	24 h	24 h	Regulation No. 21/2008

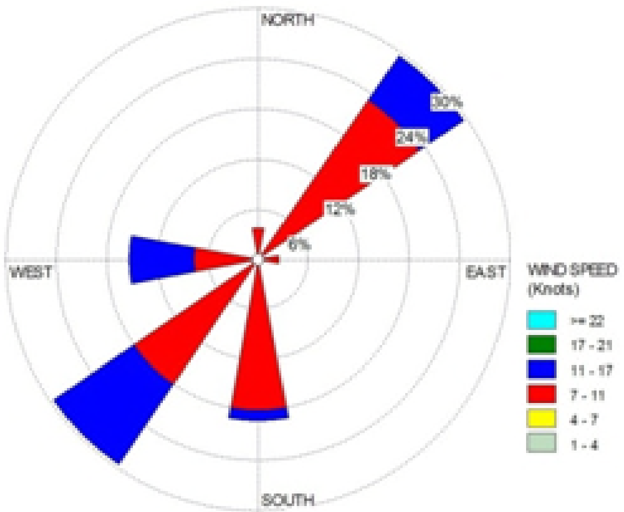

Fig 2. Wind rose in 2001–2011 from Cengkareng Monitoring Station

FDG be added as the emission ranges were close to the Threshold Limit Value. Besides, NO_2 parameter has far exceeded the standard emission in all scenarios, thus a tool was needed in order to reduce NO_2 such as using a combustion system with low NO_2 system (Low NO_x Burner). Moreover, TSP parameters needed an additional tool such Electrostatic Precipitator (ESP) because the amount of dust would be disruptive and far above standard emission if it was without ESP installation.

Pollutant Dispersion into Ambient Air

Wind direction data showed that the dominant wind direction was blowing from Southwestern and Northeast at speeds ranging from 7-11 knots. The wind roses overview was presented in Fig. 2.

The modeling results of pollutant dispersion into the environment was done by modeling the distribution of pollutants using Gaussian Plume equation taking into account with the wind direction and calculate existing power plant condition on activity areas. Air quality measurement has been conducted on June, 22 – May, 23, 2012 around the operated area of Banten 3 power plant. Ambient air sampling was conducted to determine the condition of the ambient air around the power plant. Sampling points distance were various starting from the closest point on the power plant project site area, then taken into 0-5 km around the power plant site. The measurement results of ambient air were presented in Table 6.

The monitoring results of ambient air quality in Banten 3 power (Table 6) showed that the air condition was in good condition. It can be seen that the location has still natural condition with most areas are agriculture and gardens. Some locations for SO_2 concentrations were relatively high because there were people activities such burning garbage and agriculture waste (straw).

PT PLN (Persero) plan to build the power plant 1 x 660 MW capacity would produce more pollutant gas concentrations in the ambient air. Dispersion modeling results for each scenario was performed using the worst case scenario on which the calculation was selected using atmospheric conditions which will give maximum exposure to the ambient air. The flue gas out temperature was 393 K in rural area. The results of the pollutant dispersion were presented in Fig. 3.

Based on the results of the dispersion calculations, it showed that all the parameters (SO_2, NO_2, CO, and TSP) met the national ambient air quality

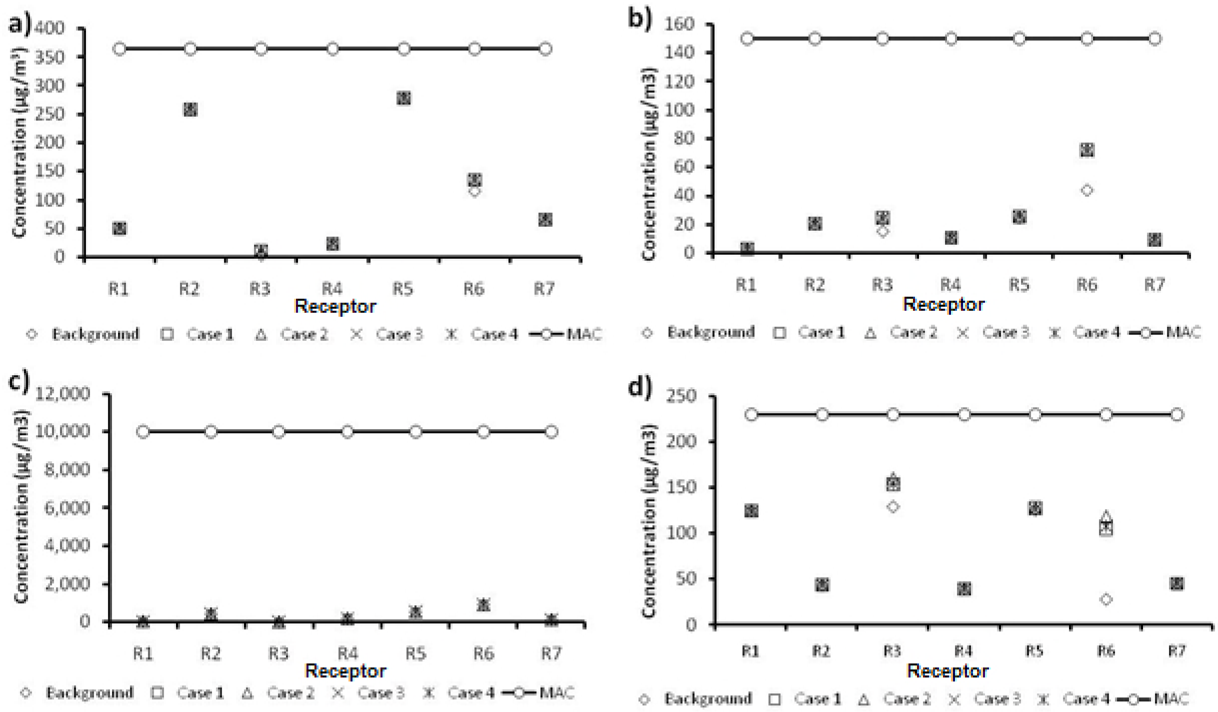

Fig 3. Pollutant gas concentration into the receptor (a) SO_2, (b) CO, (c) NO_2, (d) TSP (Note: Maximum Allowable Concentration is based on Indonesian Government Regulation No. 41 1999)

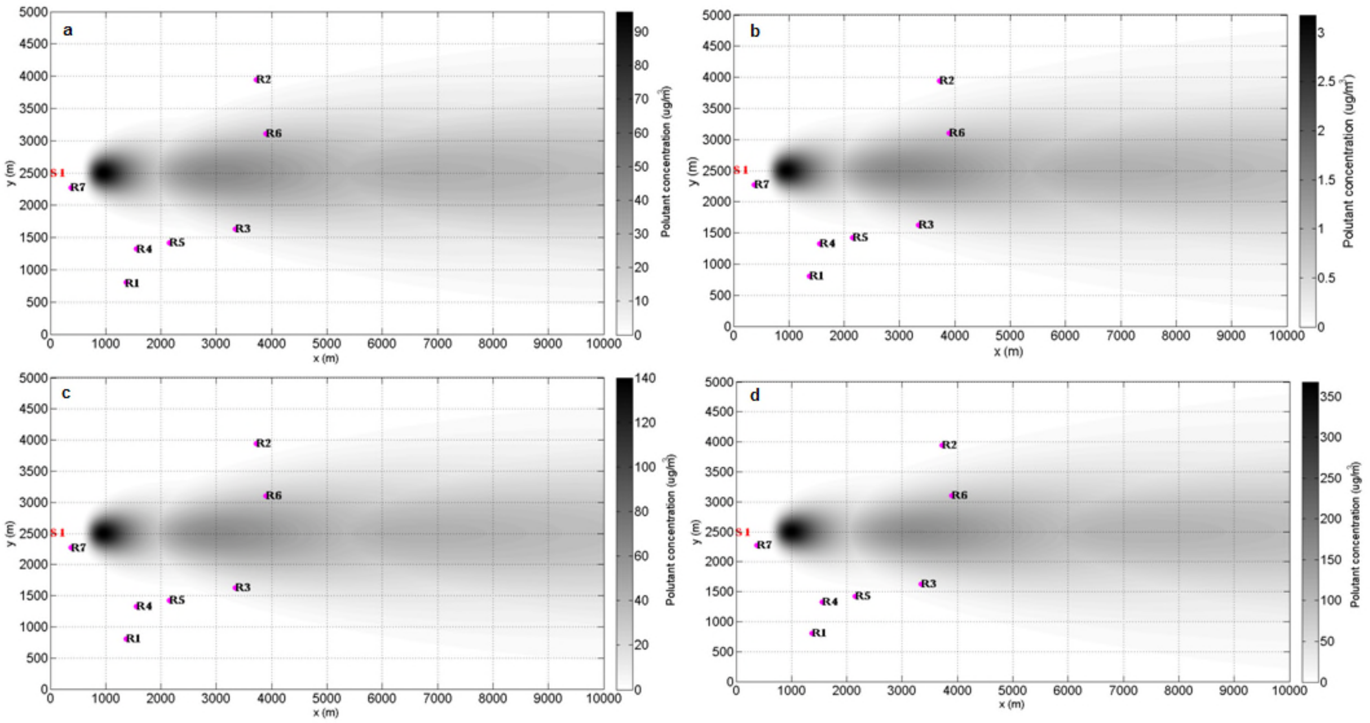

Fig 4. Dispersion of pollutant gases case 1(a) SO_2, (b) CO, (c) NO_2, (d) TSP

standard. Air pollutant dispersion from a single stack scenario and stack separated as far as 43 m showed much different results. The dispersion results for separated stack have tendencies for increasing the maximum concentration distribution and shorten the maximum concentration distance. This phenomenon was due to separated stack would produce lower flow rate pollutant.

Through the calculation results of the ambient air quality on power plant location taken at the maximum dispersion estimated point from the existing power plant showed that the additional concentration of NO_2 and TSP as the result of the increase of power plant capacity. Otherwise, it was not expected to exceed ambient air quality standard. NO_2 and TSP pollutant gases can give effect on human health whose affected to pollutant gas exposure in high concentrations. The distribution of each pollutant gases were presented in Fig. 4.

CONCLUSION

It can be concluded through the simulation results that increasing of plant capacity will also increase the pollutant emissions. SO_2 gas on case-1 and case-2 and NO_2 and TSP on all scenarios were exceeding the emission standards, according to Environment Ministry Regulation No. 21/2008. The determination of ambient air concentration on residential location around the power plant indicates that ambient air concentrations received by receptors are still below the Threshold Limit Value in accordance with Government Regulation No. 41/1999.

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