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Impact of Oil Well Exploration on Ambient Air Quality Change

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Abstract— Five potential oil wells located in West Java offshore area were explored in order to characterize the predicted oil and condensate production in the next upcoming operation years. The oil wells were hoped to supply the gas need of industries in Java Island. The oil wells area was located about 1.5-10.5 km away from West Java shore. During oil well exploration a huge amount of gas was burned. The first objective of the research was to estimate the main gaseous pollutants, i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and volatile organic compound (VOC) resulted from oil well exploration activity. The second objective was to simulate the dispersion of gaseous pollutant resulted by the gas burning during the exploration period in the ambient air. Estimated amount of the emitted gaseous pollutants was based on burned gas amount and emission factor compiled by US-EPA. The dispersion simulation of gaseous pollutants in the ambient air was based on Gaussian dispersion model as well as climatology data compiled by Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG). Research result showed that if the predicted burned gas was 1.65 MMSCFD then the emission rate of SO_2 was about $5.2*10^3$ µg/s, whereas CO, NO_2 and VOC were $7.3*10^5$ µg/s, $2.4*10^6$ µg/s, $4.8*10^4$ µg/s, respectively. Simulation of the gaseous pollutant indicated that the surrounding area of the exploration site was relatively safe as based on the analysis result where the highest ambient concentration of the gaseous pollutants were considerably below the pertinent threshold limit.

Index Terms— ambient air quality, carbon monoxide, nitrogen dioxide, oil well exploration, sulphur dioxide.

1 Introduction

By end of 2014, it was estimated that oil and gas need for Java Island reaches 0.74 MBPD (mega barrel per day) and 2500 MMSCFD (million standard cubic feet per day), respectively. It would be supplied by national and multinational companies holding production sharing contracts (PSC) with Government of Indonesia and were operated in a number of oil and gas fields in Indonesia including northern offshore of Java Island. During oil well exploration a huge amount of gas was burned.

One of the main environmental problems associated with the oil and gas exploration activities is the impact of the waste gas release into the atmosphere during the exploration phase. The waste gases produced by flares and other equipments are then simply released into the ambient air without any treatment previously.

The first objective of this research was to estimate the emission rate of main gaseous pollutants, i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and volatile organic compounds (VOC) resulted from the oil wells exploration activity. The second objective was to simulate the dispersion of the gaseous pollutants resulted by the gas burning during the exploration period in the ambient air. The third objective was to justify the safety status of the ambient air in the area of oil well exploration.

2 Materials and Methods

The parameters of ambient air quality change involved in this assessment were limited to primary ones, i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and volatile organic compounds (VOC). The threshold limits of the relevant parameters of ambient air gas concentration refer to national regulation namely PP No. 41/1999 pertaining on Air Pollution Control.

The amount of the emitted pollutants released into the ambient air was calculated based on a number of definitions and assumptions. The first one was that the amount of burned gas was contributed by flared gas and the gas consumed by a power generator, i.e. 0.45 MMSCFD and 1.2 MMSCFD, respectively. Therefore, total burned gas was 1.65 MMSCFD. Secondly, emission factors for SO_2, NO_2, CO and VOC refer to US-EPA (United States Environmental Protection Agency) Standard. Thirdly, average monthly wind speed (i.e. 1.2 m/s), used to support pollutant dispersion simulation was based on climatology data compiled during 12 years by National Agency for Meteorology, Climatology and Geophysics (BMKG) of Indonesia. The fourth assumption is that stack height as pollutant point source was 20 m above ground level.

The amount of pollutants resulted from the combustion of the gas during oil well exploration phase is presented in form of calculation sheet (Table 1). The sequence of the research steps are as follows:

1. Emission rate calculation of the primary gaseous pollutants
2. Running the dispersion simulation
3. Justification of ambient air safety status.

From the field identification it was clearly found that the sources of the burned gas items were a flare and a power generator. The next step, i.e. emission rate calculation was based on the burned gas amount and the associated emission factors. The emission factors were adopted from the US-EPA (United States Environmental Protection Agency) emission factor compilation, especially AP-42 Standard, Chapter 1.4 pertaining on Natural Gas Combustion. The dispersion simulation was run by using Gaussian Dispersion Model with climatological data input including wind speed and wind direction. The last step of the research sequence, i.e. ambient air safety status justification was based on

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pertinent national standard namely Government Regulation No. 41/1999 pertaining on Air Pollution Control. The amount of the emission rate can be expressed as follows:

$$E = n * e \qquad (1)$$

where E is emission rate of the gaseous pollutant [μg/s], n is amount of the burned gas [g/s], e is relevant emission factor for the natural gas [μg/g], i.e. for SO_2, CO, NO_2 and VOC.

In order to run dispersion simulation it is necessary first to calculate the amount of the generated primary pollutants. It was then used as input for dispersion simulation of the gases in the ambient air.

Equation 2 shows an expression model for pollutant dispersion in the ambient air as was simulated by using Gaussian dispersion model [1], [2], [3], [4], [5]. On the ground level, the expression of the pollutant concentration where the plume height is H, y = 0 and z = 0 is as follows:

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

where $C_{(x,y,z)}$ is concentration of gas at any point coordinate (x,y,z) [g/m^3], Q is stack emission rate [g/s], σ_y and σ_z are dispersion coefficient according to Pasquill-Gifford curve [m], U is wind speed [m/s], y is distance of any point along the y-axis to the centre line [m], z is vertical distance along z-axis from centre line [m] and H is plume height from the ground level [m].

3 Results and Discussion

Estimation of gasesous pollutants generated from burning of 1.65 MMSCFD natural gas during the oil well exploration phase is presented in Table 1.

It shows that the emission rate of sulphur dioxide was merely $5.2*10^3$ μg/s as it was caused by its low emission factor. This is due to the fact that natural gas contains only a small number of sulphuric compounds such as H_2S. On the other side, however, the generated nitrogen oxyde (NO_2) was extremely high due to its

TABLE 1
Gaseous Pollutant Generated from Burning of 1.65 MMSCFD Gas

Component	Unit	Primary gaseous pollutants			
		SO_2	CO	NO_2	VOC
Emission factor	lb/MMSCF	0.6	84	280	5.5
Emission rate	lb/d	1.0	138.6	462.0	9.1
	μg/s	$5.2*10^3$	$0.7*10^6$	$2.4*10^6$	4.8*10

SO_2 = sulphur dioxide, CO = carbon monoxide, NO_2 = nitrogen dioxide, VOC = volatile organic compound.

high emission factor as indicated by US-EPA standard. Dispersion simulation of four main gaseous pollutants, i.e. SO_2, CO, NO_2 and VOC are presented in Figure 1, 2, 3 and 4.

Figure 1 indicates that concentration of SO_2 in ambient air was very low even in the area that was extremely closed to the oil well exploration site. The maximum concentration was merely 0.6μg/m^3 whereas the national threshold limit for this parameter is 365 μg/Nm^3. This was caused by the quality of the burned gas where the sulphur content was very low as indicated by a lesser emission factor. The emission factor compiled by US-EPA was based on an assumption where 100% fuel sulphur was converted to SO_2.

In the atmosphere, SO_2 plays an important role in the acid rain formation. SO_2 is also known as corrosive and poisonous gas. If the gas is released in the atmosphere then it could be converted chemically into sulphate which is then deposited as acid rain. At high concentrations, SO_2 affects breathing and produces respiratory illness, alterations in the defences of the lungs and aggravation of exiting respiratory and cardiovascular disease as well as produce foliar damage on trees and agricultural crops [6].

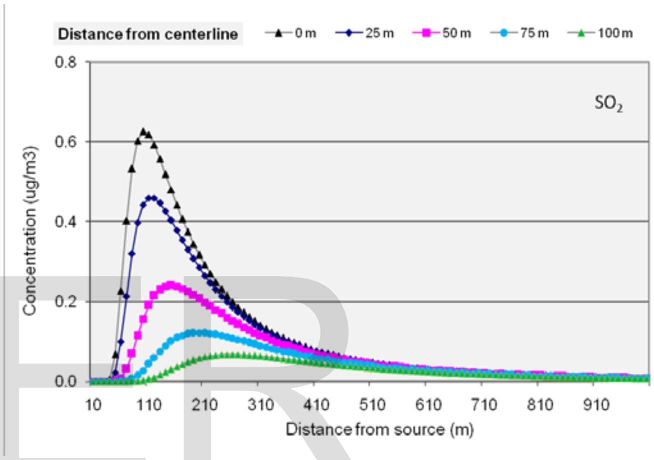

Fig. 1. Dispersion simulation of sulphur dioxide (SO_2) in ambient air. The relevant threshold limit is 365 μg/Nm^3.

Coal-fired power plants are the worst SO_2 polluters [7]. In the environment SO_2 is known as one of primary air pollutants in ambient air. The gas in the air originates from a number of sources such as coal and oil fired power plants and a lot of industrial processes involving fossil fuel combustion [8].

Carbon monoxide (CO) shows a similar behaviour as SO_2 where its maximum concentration in ambient air was merely 88 μg/Nm^3 (Figure 2), a level of normal daily situation in Indonesia and Germany [9] where the threshold limit according to PP No.41/1999 is 10,000 μg/Nm^3.

If CO in ambient air is inhaled by human being then it would impairs the oxygen (O_2) carrying capacity of blood by combining with haemoglobin (Hb) to form carboxy-haemoglobin (CO-Hb). For concentrations of CO as high as 1000 ppm, at normal atmospheric pressure, the partial oxygen pressures in aveoli and arterial blood will not be significantly reduced [10].

If the percentage of CO-Hb exceeds about 2 per cent, health is temporary impaired, and this level occurs in people engaged in heavy physical activity if the ambient CO level is greater than about 30 ppm (≈ 35,000 μg/Nm^3) [3].

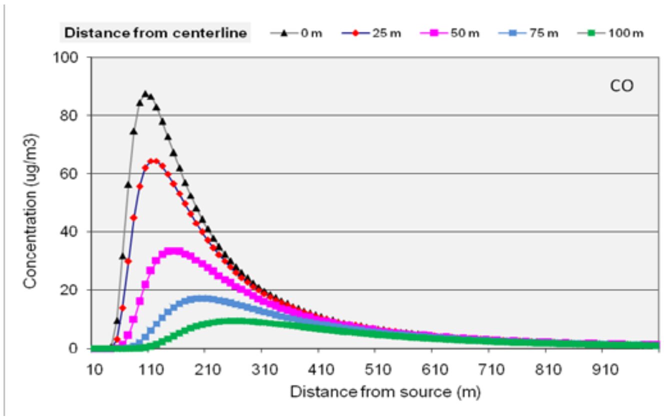

Fig. 2. Dispersion simulation of carbon monoxide (CO) in ambient air. The relevant threshold limit is 10,000 µg/Nm^3.

The dispersion simulation of NO_2 expressed in Figure 3 shows that the maximum concentration of nitrogen dioxide (NO_2) in ambient air along the centerline was 292 µg/Nm^3, a level which is greatly exceeds the threshold limit (150 µg/Nm^3) according to PP No. 41/1999. The figure also indicated that area whose distance from the source more than 200 m is a safe area since the concentration of NO_2 less than the threshold limit. It means that the status of the ambient air in this area was safe for the human being. Research result of NO_2 impact on human being [11] indicated that decrement in lung function indices associated with increasing concentrations of NO_2 and particulate matter.

The last primary gaseous pollutant under concern, i.e. VOC, shows a similar pattern as others where the maximum concentration is ± 5.5 µg/Nm^3 (Figure 4) which is considerably under the threshold limit of 160 µg/Nm^3.

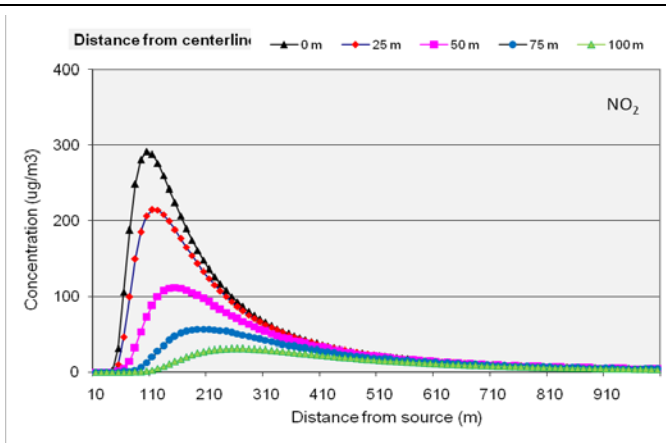

Fig. 3. Dispersion simulation of nitrogen dioxide (NO_2) in ambient air. The relevant threshold limit is 150 µg/Nm^3.

The above mentioned results reveals that the concentrations of three from four primary ambient air parameters are under the threshold limit according to national guideline (PP No. 41/1999) in all area surrounding the emission source whereas for parameter of NO_2 the safe area starts from radius of more than 200 m. This result of the study indicates that in general the area whose distance from the emission source more than 200 m is a relatively safe area. In this safe area the primary gaseous pollutants concentration comply with the pertinent national standard.

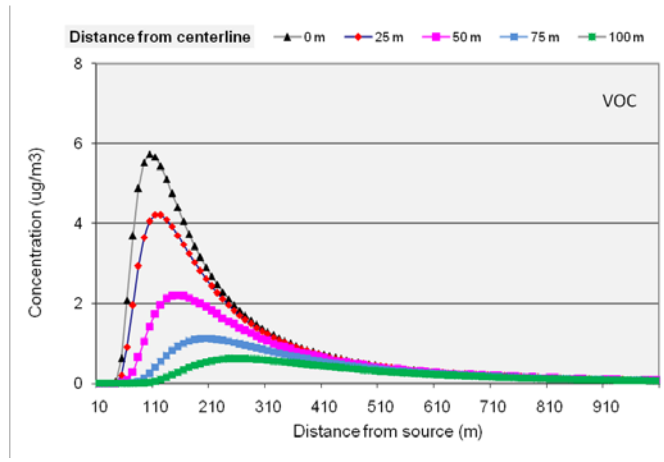

Fig. 4. Dispersion simulation of volatile organic compound (VOC) in ambient air. The relevant threshold limit is 160 µg/Nm^3.

4 Conclusion

Conclusions that can be drawn from the study are as follows:

a. The predicted burned gas during oil well exploration was 1.65 MMSCFD and the emission rate of SO_2 was about $5.2*10^3$ µg/s, whereas CO, NO_2 and VOC were $7.3*10^5$ µg/s, $2.4*10^6$ µg/s, $4.8*10^4$ µg/s, respectively.
b. Dispersion simulation of the emitted gaseous pollutants during the exploration period resulted in maximum concentration of SO_2 in ambient air about 0.6µg/Nm^3 whereas for CO, NO_2 and VOC were 88 µg/Nm^3, 292 µg/Nm^3 and 6 µg/Nm^3, respectively.
c. The ambient air in the area of oil well exploration site was relatively safe due to the local condition where the primary gaseous pollutants concentration comply with the pertinent national standard.

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