Air dispersion modelling of gas turbine power plant emissions in Makassar by using AERMOD

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Abstract. Activities at PT. PLN (Persero) Makassar Tello Sector especially Gas Turbine Power Plant produces exhaust emissions that can be pollution for the environment if the quality is not monitored. Therefore, an analysis of the pattern distribution of exhaust emissions in Gas Turbine Power Plant needs to be done to determine the concentration produced and dispersion pattern and direction of its spread. The modeling in this study uses AERMOD software and requires meteorological support data and ground elevation to run the software. The results showed that the distribution of SO\(_2\), NO\(_2\), CO, and particulates gas pollutants was in line with the dominant wind direction found in windrose. The concentration received by the receptors is very small and does not exceed the ambient air quality standards based on South Sulawesi Governor Regulation Number 69 of 2010 which is 365 \(\mu\)g/Nm\(^3\) for SO\(_2\), 150 \(\mu\)g/Nm\(^3\) for NO\(_2\), 10,000 \(\mu\)g/Nm\(^3\) for CO, and 230 \(\mu\)g/Nm\(^3\) for particulates. Thus, the impact received by the receptor is not felt directly.

1. Introduction
Makassar is the capital of South Sulawesi which is one of highest population growth city in Indonesia. To meet electricity needs, in 1970 PT. PLN (Persero) Makassar Tello Sector was build with Steam Power Plant (PLTU) to supply electricity needs in Makassar City and surrounding areas. As the population growth rate increases and requires greater electricity supply, PT. PLN (Persero) Makassar’s Tello sector is adding power generation units such as PLTD and PLTG. From these activities it will potentially produce more exhaust emissions that will be discharged into the air. Gas emissions from power plants chimney released into the air are such as NO\(_x\), SO\(_x\), CO, CO\(_2\), particulates, Hydrocarbons, heavy metals, and other compounds generated from the combustion [1].

PT. PLN (Persero) Makassar Tello Sector has one power plant unit, namely GE 2 PLTG unit where this PLTG can produce power of 30 MW with the fuel used is HSD (High Speed Diesel). The GE 2 PLTG unit in operation will produce exhaust emissions such as SO\(_2\), NO\(_2\), CO, and particulates. The resulting emissions must be measured whether it is in accordance with South Sulawesi Governor Regulation Number 69 of 2010. Currently around PT. PLN (Persero) Makassar’s Tello Sector has been populated by residential areas. Inevitably, the power plant activities especially GE 2 PLTG units will have an impact on the surrounding environment. Thus the need for research on the distribution of emissions sourced from power plants located at PT. PLN (Persero) Makassar Tello Sector especially the Gas Power Plant (PLTG). This study takes a case study to determine the distribution of emissions produced with SO\(_2\), NO\(_2\), CO and Total Particulate parameters in accordance with South Sulawesi Governor Regulation No. 69 of 2010 for 7 semesters starting in 2015 until early 2018. After obtaining
emission gas levels analyzed using emission gas analyzer, it can be seen the distribution patterns that have been dispersed for a certain time from these emissions with AERMOD software. AERMOD is a software to model the dispersion of a gas produced a certain distance and time and the resulting distribution pattern. In processing data on AERMOD, other software such as WRPlot View, AERMET View and AERMAP are also needed [2]. The objectives of this study are as follows: 1) Analyzing the level of concentration of gas emissions (SO₂, NO₂, CO and total particulates) produced by the PLTG chimney located in PT. PLN (Persero) Makassar Tello Sector, and 2) Analyzing the distribution pattern concentration of gas emissions (SO₂, NO₂, CO and total particulates) produced by PLTG chimneys located in PT. PLN (Persero) Makassar Tello Sector by using the AERMOD model.

2. Methodology
The location of this research is located at PT. PLN (Persero) Makassar Tello Generating Sector, with the object of research is the GE 2 PLTG chimney unit. The coordinates of the observation object is at S: 05° 08' 51.1" and E: 119° 28' 17.6". This research that began with the sampling of gas emissions from GE 2 was conducted on 7 March 2018, which is in accordance with the emission sampling schedule by the analysis services laboratory.

In this research several materials and tools are used to take samples and process data as follows:
- The impinger tube is a place to put the absorbent liquid.
- Filter paper is a material used to filter particulates from chimney emissions.
- Impinger is a tool to measure emissions of emissions by wet analysis.
- Emissions Stick Sampler is a tool for taking particulate samples and exhaust emissions in the research object, the chimney.
- Google Earth is software that is used as a tool to display maps of measurement locations and targets from observations.
- The camera is a device used to record documentation during sampling.
- WRPLOT is software that is used as a tool to make windrose.
- AERMOD is software that is used as a tool to model the distribution pattern of exhaust emissions.

In conducting data retrieval, primary data and secondary data are used. Primary data obtained from the results of sampling (sampling) exhaust gas emissions from GE 2 in the first semester of 2018. Gas emissions sampling was carried out together with the laboratory analysis services (third parties) as routine monitoring conducted by the company every semester. While secondary data is obtained from exhaust emission measurement data in the first and second semester of 2015, 2016, 2017 and 2018. This data can be seen from the RKL RPL Report Data at PT. PLN (Persero) Makassar Tello Generating Sector. Meteorological data were obtained from the Agency for Meteorological, Climatological and Geophysics (BMKG) Region IV Makassar. Meteorological data obtained include cloud cover, wind speed, wind direction, temperature, humidity, air pressure, lowest cloud height, rainfall, and solar radiation [3]. The stages of this research are as follows. After obtaining the required data, the data processed to make windrose with WRPLOT software. For meteorological data and Upper Air data are processed using AERMET View. To obtain the number of emission rate, calculated emissions data can be processed using AERMOD View. In the data processing in AERMOD View, elevation and map data must be included so that the AERMAP that is inside AERMOD will be able to model the distribution pattern of emissions produced by GE 2 chimney of PLTG (SO₂, NO₂, CO and particulates). The results of the modeling will produce an isopleth where each color represents the concentration range of pollutant gases.

3. Results and discussion

3.1. Data emissions
Based on South Sulawesi Governor Regulation No. 69 of 2010 measuring exhaust gas emissions at PT. PLN (Persero) Makassar's Tello Sector shows that the concentration of SO₂, NO₂, and Particulate
gas pollutants does not exceed the quality standard of 1000, 800, and 150 mg / m³ for each gas in each semester. CO gas in 2015 had exceeded the quality standard of 600 mg / m³. However, in the following year up to 2018 the quality standard did not exceed due to reduced workload from the GE 2 unit and periodic maintenance. The tabulation of results is as follows:

### Table 1. Emission data.

| Time of Resource | Concentration (mg/m³) |
|------------------|-----------------------|
|                  | SO2       | NO2       | CO        | Particulate |
| I 2015           | 34.68     | 30.05     | 652.76    | 9.22        |
| II 2015          | 38.30     | 34.30     | 767.28    | 23.11       |
| I 2016           | 71.72     | 32.78     | 270.27    | 22.00       |
| II 2016          | 4.40      | 2.40      | 70.00     | 58.32       |
| I 2017           | 1.00      | 1.00      | 33.62     | 1.20        |
| II 2017          | 38.85     | 1.00      | 17.00     | 2.02        |
| I 2018           | 35.98     | 8.62      | 70.83     | 10.40       |

### Table 2. Emission rate.

| Debit (m³/s) | SO2 | NO2 | CO | Particulate |
|--------------|-----|-----|----|-------------|
| 4.71         | 4.08| 88.63| 1.25|
| 5.20         | 4.66| 104.18| 3.14|
| 9.74         | 4.45| 36.70| 2.99|
| 0.60         | 0.33| 9.50 | 7.92|
| 0.14         | 0.14| 4.56 | 0.16|
| 4.89         | 1.17| 9.62 | 1.41|
| 135.77       |     |     |    |             |

### 3.2. AERMOD modeling results

This sub-chapter explains the results of modeling carried out using AERMOD for each semester in the form of isopleth concentrations. This sub-chapter also explains the graph of the relationship between concentration and distance for an average of 24 hours in each semester that is observed based on the wind direction, the relationship between concentrations at a certain hour to distance, and the relationship between concentration and distance for an average of 24 hours with a predetermined wind direction which is southeast.

- **Modeling Results of Semester I 2015**

  After being dispersed for 24 hours, figure 1 (a), (b), (c), and (d) showed that the maximum concentrations of SO₂, NO₂, CO and Particulates are 0.07472 µg / m³, 0.06328 µg / m³, 1.40612 µg / m³ and 0.01985µg / m³. The maximum concentration is located at UTM 773950 m and 9430445 m or occurs at a distance of 77.78 m to the southwest of the source of the research object.
Figure 1. Windrose Semester I 2015.

(a) Isopleth SO$_2$

(b) Isopleth NO$_2$

Figure 2. Isopleth Semester I 2015 on the average 24 Hours.

SO$_2$, NO$_2$, CO, and particulate concentrations decrease when the distance getting further as the same result phenomena that shown the pollutans will decrease when the distance getting further [4]. This is occurred because the emission of gas discharged by the chimney is dispersed directly into the environment so that the direct gas emission decreases and does not exceed the air. After the exhaust gas emissions from the GE 2 chimney generated and dispersed for 24 hours, figure 3 (a), (b), (c), and (d) showed that the maximum concentrations of SO$_2$, NO$_2$, CO and particulates are 0.23823 μg / m$^3$; 0.21349 μg / m$^3$; 4.77288 μg / m$^3$ and 0.14386 μg / m$^3$. The maximum concentration is located at UTM 773950 m and 9430445 m or occurs at a distance of 77.78 m to the southwest of the source. SO$_2$, NO$_2$, CO, and particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of SO$_2$, NO$_2$, CO, and Particulates which is 0.23823 μg / m$^3$, respectively; 0.21349 μg / m$^3$; 4.77288 μg / m$^3$; 0.14386 μg / m$^3$ at a distance of 77.78 m. After that the concentration will continue to decrease up to a radius of 1 km. This condition did not exceed the air quality standards.
On Semester I 2016, after the exhaust gas emissions from the GE 2 chimney generated and dispersed for 24 hours, figure 14 (a), (b), (c), and (d) showed that the maximum concentrations of SO$_2$, NO$_2$, CO, and particulates are 0.39137 μg / m$^3$; 0.17881 μg / m$^3$; 1.47466 μg / m$^3$ and 0.12014 μg / m$^3$. The maximum concentration is located at UTM 773950 m and 9430445 m or occur at a distance of 77.78 m to the northwest of the source of the emissions.

SO$_2$, NO$_2$, CO, and Particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of SO$_2$, NO$_2$, CO, and Particulates which is 0.39137 μg / m$^3$, respectively; 0.17881 μg / m$^3$; 1.47466 μg / m$^3$; 0.12014 μg / m$^3$ at a distance of 77.78 m.

On Semester II 2016, after being dispersed for 24 hours, exhaust gas emissions from the GE 2 chimney are presented in figure 17 (a), (b), (c), and (d) showing that the maximum concentrations of SO$_2$, NO$_2$, CO and Particulates are 0.15288 μg / m$^3$; 0.08408 μg / m$^3$; 2.42056 μg / m$^3$ and 2.01798 μg
/ m$^3$. The maximum concentration is located at UTM 774610 m and 9430005 m or occurs at a distance of 781.70 m to the southeast from the source of the research object.

Figure 5. Isopleth semester II 2016 on the average 24 hours.

$\text{SO}_2$, $\text{NO}_2$, $\text{CO}$, and particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of $\text{SO}_2$, $\text{NO}_2$, $\text{CO}$, and particulates which is 0.15288 μg / m$^3$, respectively; 0.08408 μg / m$^3$; 2,42056 μg / m$^3$; 2,011798 μg / m$^3$ at a distance of 781.7 m. After that the concentration will continue to decrease to a 1 km radius with 0.133 μg / m$^3$ for $\text{SO}_2$, 0.0733 μg / m$^3$, for $\text{NO}_2$, 2.1 μg / m$^3$ for $\text{CO}$ and 1.75 μg / m$^3$ for particulates. When compared with the air quality standards, the results of this measurement did not exceed the required quality standards.

On Semester I 2017, after being dispersed for 24 hours, exhaust gas emissions from the GE 2 chimney are presented in Figures 20 (a), (b), (c), and (d) showing that the maximum concentrations of $\text{SO}_2$, $\text{NO}_2$, $\text{CO}$ and Particulates are 0.00292 μg / m$^3$; 0.00677 μg / m$^3$; 0.09499 μg / m$^3$ and 0.00333 μg / m$^3$. The maximum concentration is located at UTM 773950 m and 9431545 m or occurs at a distance of 1,046 m to the north of the source.

Figure 6. Isopleth semester I 2017 on the average 24 hours.
SO₂, NO₂, CO, and particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of SO₂, NO₂, CO, and particulates which are 0.00272 μg / m³, respectively; 0.00634 μg / m³; 0.0879 μg / m³; 0.00285 μg / m³ at a distance of 290 meters to 1046 meters. In this semester the wind speed blows from a low force (calm wind) to a high speed to the north causing the concentration to fluctuate. When compared with the air quality standards, the results of this measurement did not exceed the required quality standards.

On semester II 2017, after the exhaust gas emissions from the GE 2 chimney generated and dispersed for 24 hours, figure 23 (a), (b), (c) and (d) showed that the maximum concentrations of SO₂, NO₂, CO and particulates are 1.852 μg / m³; 0.0492 μg / m³; 0.81179 μg / m³ and 0.09488 μg / m³. The maximum concentration is located at UTM 774610 m and 9430005 m or occurs at a distance of 320 m to the southeast from the source of the research object.

![Figure 7. Isopleth Semester II 2017 on the average 24 Hours](image)

SO₂, NO₂, CO, and particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of SO₂, NO₂, CO, and particulates which are 1.852 μg / m³, respectively; 0.0492 μg / m³; 0.81179 μg / m³; 0.09488 μg / m³ at a distance of 320 m. After that the concentration will continue to decrease to a 1 km radius with 0.527 μg / m³ for SO₂, 0.0149 μg / m³, for NO₂, 0.242 μg / m³ for CO and 0.0287 μg / m³ for particulates. When compared with air quality standards, the results of this measurement did not exceed the required quality standards.

On Semester I 2018 After being dispersed for 24 hours, exhaust gas emissions from the GE 2 chimney in Figures 26 (a), (b), (c), and (d) showed that the maximum concentrations of SO₂, NO₂, CO and particulates are 0.18584 μg / m³; 0.04446 μg / m³; 0.3656 μg / m³ and 0.05359 μg / m³. The maximum concentration is located at UTM 773840 m and 9430555 m or occurs at a distance of 173 m to the northwest of the source of the research object where at that distance is a residential area.

SO₂, NO₂, CO, and Particulate concentrations decrease when the distance is getting further. Emissions coming out of the chimney are directly dispersed so that the concentration decreases and then continues to increase until reaching a maximum concentration of SO₂, NO₂, CO, and particulates which are 0.18584 μg / m³, respectively; 0.04446 μg / m³; 0.3656 μg / m³; 0.05359 μg / m³ at a distance of 173 m. After that the concentration will continue to decrease up to a 1 km radius of 0.0965 μg / m³ for SO₂, 0.0289 μg / m³, for NO₂, 0.151 μg / m³ for CO and 0.0224 μg / m³ for particulates. When compared with the air quality standards, the results of this measurement did not exceed the required quality standards. The pattern will made as we know as a spatial pattern [5].
4. Conclusion

Based on the objectives of this study which are based on the results of research and data analysis, the following conclusions are obtained that the results of the measurement of the GE 2 unit of PLTG emissions for SO$_2$, NO$_2$, CO and Particulate parameters fluctuate every semester. Specifically CO parameters in 2015 is the only condition that has exceeded the air quality standard of 600 mg / m$^3$ in Environmental Government Regulation No. 21 of 2008. Other gas parameters did not exceed the quality standards stipulated in the South Sulawesi Governor Regulation No. 69 of 2010 amounting to 1000 mg / m$^2$ for SO$_2$ gas, 800 mg / m$^2$ for NO$_2$ gas, and 150 mg / m$^2$ for particulates. The distribution pattern of emission from SO$_2$, NO$_2$, CO and Particulate pollutants in accordance with the dominant wind direction contained in windrose showed that the location exposed to pollutant gas is the location of PT. PLN (Persero) Makassar Tello Sector and surrounding settlements. Nevertheless, the
concentration received by the receptor did not exceed the air quality standard stated by the Governor of South Sulawesi Regulation No. 69 of 2010 for 24 hours of measurements which is 365 μg / Nm$^3$ for SO$_2$ gas, 150 μg / Nm$^3$ for NO$_2$ gas, 10000 μg / Nm$^3$ for CO gas and 230 μg / Nm$^3$ for particulates.

5. References

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