

AERMOD Modeling Analysis of CO And NOx Parameters from Diesel Generator Emission Sources in the Coal Mining Industry

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Abstract: Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 4 of 2021: All types of businesses and activities must manage environmental impacts. Emissions resulting from the use of heavy equipment in the operational activities of the coal mining industry, such as scrapers, dump trucks, loaders, excavators, and bulldozers. In addition to heavy equipment, exhaust emissions are generated from the use of generators that operate longer than 1,000 hours per year. The resultant emissions will have a long-term impact on air quality around business activities. In an effort to tackle the spread of air pollution, modeling is carried out which aims to analyze emission air dispersion patterns by measuring exhaust emissions with Nitrogen Dioxide (NOx) and Carbon Monoxide (CO) test parameters in industrial activity areas with AERMOD applications and can predict emission air dispersion patterns dispersed into the air based on the distance and concentration of particles. One of the models used is the Gaussian Plume Model. Modeling is done by processing data from the meteorological section with AERMOD software, which will then provide a distribution pattern that is close to the true value. Modeling is carried out with a radius of 5,000 meters and data from emission measurements from the power generation unit. Based on the modeling results, the CO parameter emission dispersion obtained the highest value in February with a value of $30.4 \mu\text{q}/\text{m}^3$ and the lowest value in March with a value of $3.43 \mu\text{q}/\text{m}^3$. As for the NOx parameter, the highest dispersion value was in June at $6.21 \mu\text{q}/\text{m}^3$, and the lowest value was in January at $3.51 \mu\text{q}/\text{m}^3$. This research was conducted in March 2023. It is located on the project site of the Coal Mining Industry area with a mining business permit (IUP) area of 2936.14 ha in Mekar Jadi Village, Sungai Lilin District, Musi Banyuasin Regency, South Sumatra Province.

Keywords: Mining Industry, Air pollution, Emissions, Air pollution dispersion, software AERMOD

1. Introduction

Air pollution takes place when the atmosphere undergoes alterations caused by excessive pollutants, leading to a decline in the overall quality of the air. Air pollutant emissions from business or industrial activities are highly dependent on the type of activity, process, industrial equipment, and utilities used during the activity [1]. Based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 4 of 2021, all forms of business activities and/or activities that have an impact on the environment are required to carry out environmental management. Business activities that produce exhaust emissions as a result of the combustion process originate from the heating process, engine propulsion, and generators [2].

Emissions generated come from heavy equipment such as scraper-dump trucks, loaders, grader excavators, and bulldozers. Apart from heavy equipment, other equipment such as generators, and conveyors that use fossil fuels also contribute to gas emissions. This is due to the relatively long use of

sustain. The use of a mining generator as a source of electricity, the generator used for more than 1000 hours/year, means that the emission will have an impact on the quality of the air around the region of business activity [3].

Dispersion of air pollution is influenced by the distribution of air pollution and meteorological conditions in the surrounding area. Pollutant distribution can describe the amount of air pollution that needs to be checked. One of the models is the dispersion of the Gaussian plume model. To identify the spread of pollutants, software that aids in the mapping of pollutants is required. The AERMOD model is one piece of software that is used to monitor and evaluate the toxicity of dangerous pollutants when the concentration and pattern of emission spread are known [4].

Modeling is done by processing meteorological data with AERMOD software. AERMOD is an air quality spatial dispersion model intended for compliance with regulations and can predict the distribution of air quality for up to 50 different sources

(point, area, or volume sources), besides that the distribution of air quality from mobile sources can also be predicted by software [5].

2. Material and Methods

2.1. Time and Place

This research was conducted from February 2023 until its completion. The research location is at the Coal Mining Industrial Estate Project Site in Sungai Lilin District, Musi Banyuasin Regency, South Sumatra Province. The secondary data used is data from meteorology, such as wind direction. Solar radiation, humidity, pressure, precipitation, and wind speed were obtained from the European Center for Medium-Range Weather Forecasts (ECMWF).

2.2. Tools and Materials

This study used stationary, a gas analyzer, an anemometer, and personal protective equipment. A gas analyzer is a tool used to measure the content of the exhaust gas mixture in generator emissions [6] an anemometer is used to measure wind speed. Based on the speed of the wind through a propeller [4]. Figure 1. a and b show a measuring instrument.



Figure 1. a (Anemometer), b (Gas Analyzer)

2.3. Methods

2.3.1. Meteorological Data Collection

Secondary data uses ERA-5 meteorological data obtained from the European Center for Medium-Range Weather Forecasts (ECMWF) website. These data represent hourly data [7]. The primary data is in the form of instantaneous measurements made using an anemometer with parameters such as temperature, air humidity, wind speed, and direction to measure CO and NO₂ levels in the generator using a gas analyzer [1].

2.3.2. AERMET Data Processing

Meteorological data that has been obtained from the ERA5 European Center for Medium-Range Weather Forecasts (ECMWF) website will be processed using the AERMET software. Several steps must be taken in processing meteorological data.

2.3.3. Windrose Data Processing

Depiction of wind direction and speed from all

areas within a predetermined range. Wind direction and speed can be visualized by converting meteorological data into a windrose map. This map can provide information about the distribution of wind direction and speed which is more important in carrying particulate emissions originating from generators. This data is converted into the SAMSON (sam) format, then processed using the WRPLOT View software [8].

2.3.4. DEM Data Processing

AERMAP is software that is used to measure the height of the observation field and receptors before being inserted into AERMOD to analyze the topography of an area. The AERMAP application requires terrain data to process DEM data which is available on the official website <https://tanahair.indonesia.go.id>. The scope of the study, the processed terrain data will become a base map or topographical comparison [3].

2.3.4. AERMOD Data Processing

After processing data from AERMET and Windrose, the data will then be run through the AERMOD software. The first step is to create a new project and define a reference point for the area to be studied. In this study, the coordinate system used is the Universal Transverse Mercator (UTM) with the 1984 World Geodetic System (WGS) datum, and the position of the reference point used is the southern angle with a radius of 5,000 m. At that time, enter the coordinate values (X and Y) and the dimensions of the area to be analyzed [9].

The next step is to determine the control pathway where some information is entered, such as choosing a dispersion option with an output in the form of a pollutant concentration value, determining the type of pollutant in the form of a parameter, and determining the selected deployment time according to the required period time, such as 1 hour and the period. Terrain data that has been connected to AERMOD will produce a base map that has elevation data. Each study area coordinate has an elevation contour grouped by color. The contour type used in this analysis is elevated terrain. The Profile File data that had previously been processed in AERMET was then filled in with station information: Station ID 96221, Sultan Mahmud Badaruddin II, and coordinate points E: 104° 42' 3" and S: 02° 54' 52". Then, the receptor that will be used will be determined by the location of the spread of pollutants originating from emission sources. The receptor used is a receptor with a uniform cartesian grid type [10].

The AERMOD program can be run by running the software, and a status window will appear showing the results of the data entered before the program is run. If the window has a project-complete status, then the AERMOD program can be run. The result of this software is a simulation of the spread of air emissions originating from the generator, which is depicted on the

base map with ISO concentration lines and has a color classification for each range of emission concentrations [11].

2.4. AERMOD Data Processing

Data validation is carried out through direct pollutant distribution and measurement data; validation is used to analyze the work system and see the level of accuracy of AERMOD software. The data used in the measurement of pollutant dispersion validation was measured directly at PT. X from the difference in data validation can be observed in the concentration comparison data from direct pollutant dispersion measurements using AERMOD. Limited use of mean square root difference % error (rmspe) is used to determine the error and how it occurred thus the work and its accuracy can be assessed [9].

3. Results and Discussion

Based on the research that has been done, the results of measuring generator emissions with code UE1 at coordinates (E = 104°08'41.0" and S = 02°32'53.0") with CO = 27 $\mu\text{q}/\text{m}^3$ And NOx = 244 $\mu\text{q}/\text{m}^3$. UE2 at coordinates (E = 104°09'04.8" and S = 02°33'21.5") with CO = 51 $\mu\text{q}/\text{m}^3$ and NOx = 4 $\mu\text{q}/\text{m}^3$. The measurement results will then be processed using the AERMOD application to obtain output in the form of a map of the dispersion pattern of CO and NOx emission parameters over 1 year.

3.1. Windrose

Windrose is obtained from the analysis results using the AERMET application with meteorological data processing. Meteorological data that has been processed is then applied to the AERMET application and the following results are obtained:

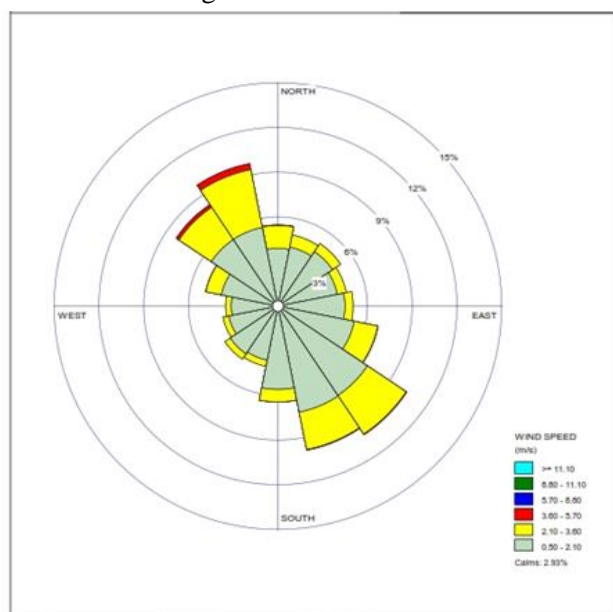


Figure 2. One-year Period Windrose

Based on the results of the analysis of the AERMET application in Figure 2, the dominant wind

direction is towards the northwest and southeast. This is due to the monsoon direction, which carries particles in the air. In December–March 2022, the dominant wind direction is to the northwest, while the dominant wind direction is to the southeast in May–September 2022. This difference is influenced by monsoons in the region around the equator, as in Indonesia, especially in Sungai Lilin Village, Musi Banyuasin Regency, and South Sumatra Province. According to [12] the concentration of a pollutant gas in the air is influenced by the meteorological conditions of the area. The meteorological factors consist of wind speed, air humidity, and temperature.

3.2. AERMOD Modeling

Emission dispersion modeling was carried out using AERMOD software by processing the measurement results of emission values at the exhaust generator. Modeling uses a radius of 5,000 meters, including data from the measurement results of emission values from two generator units with different capacities. Emission dispersion patterns are projected using color images, which respectively show the concentration levels of CO and NOx in the air. A darker or contrasting color indicates that the concentration of CO and NOx is quite high; color degradation will decrease as the concentration of CO and NOx in the air decreases. The red color indicates areas exposed to fairly high concentrations of CO and NOx, and the green color indicates areas exposed to fairly low concentrations of CO and NOx. The resulting maximum concentration value can be seen in Table 1 as follows:

Table 1. AERMOD Data

No.	month	Year	Parameters	
			CO ($\mu\text{g}/\text{m}^3$)	NOx ($\mu\text{g}/\text{m}^3$)
1	December	2021	2.80	3.60
2	January	2022	19.0	3.51
3	February	2022	30.4	4.53
4	March	2022	3.43	4.14
5	April	2022	3.16	4.20
6	May	2022	5.70	3.94
7	June	2022	7.11	6.21
8	July	2022	9.27	5.72
9	August	2022	6.40	3.82
10	September	2022	7.07	4.27
11	October	2022	5.90	3.97
12	November	2022	4.71	3.55

Based on the results of the analysis using the AERMOD application presented in Table 1, it is known that the emission dispersion of the CO parameter is at its highest value in February with a value of 30.4 $\mu\text{q}/\text{m}^3$, and the lowest value is in March with a value of 3.43 $\mu\text{q}/\text{m}^3$. As for the NOx parameter, the highest dispersion value was in June at 6.21 $\mu\text{q}/\text{m}^3$, and the lowest value was in January at 3.51 $\mu\text{q}/\text{m}^3$. These results are influenced by the generator's condition and

the materials' quality. According to [13], a combustion process that is not good will result in combustion residue in the form of CO and NOx accumulating thus the combustion process will be released directly into the air. According to [14] high concentration parameters can cause health problems and can even cause death.

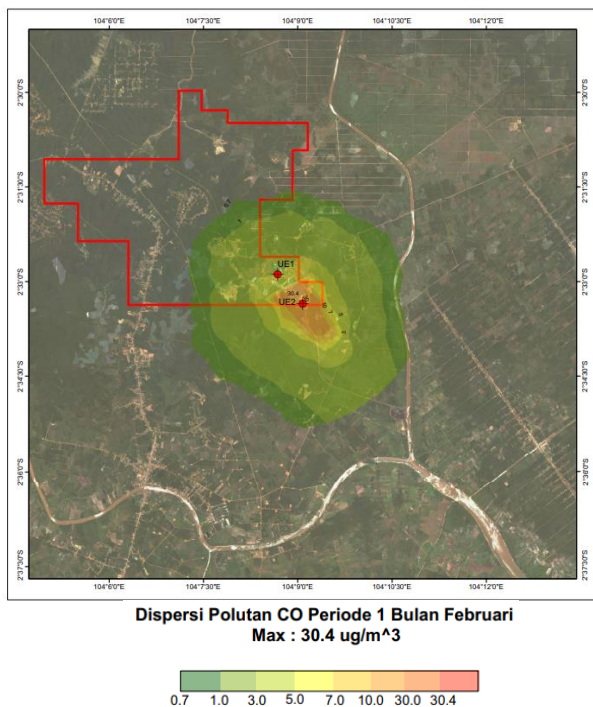


Figure 3. Highest CO Pollutant Dispersion

The findings of the AERMOD modeling will then project the pollutant dispersion pattern by giving it a color scheme based on Figure 3. The degradation in color in the figure indicates that the area where industrial coal mining activities take place has a relatively high amount of pollution, which is indicated in orange, while the residential areas nearby are indicated in green.

Figure 3's green color indicates that, in comparison to mining areas, the concentration of air emissions dispersed to residential areas is significantly lower. [10], state that in order for activities or businesses to operate in an area without having unfavorable effects that build up over time and have the potential to harm the environment, the results of emission measurements should ideally be below environmental quality standards. In this method, the dispersion of air pollution is pretty good and has little impact on the environment near the industrial coal mining activities.

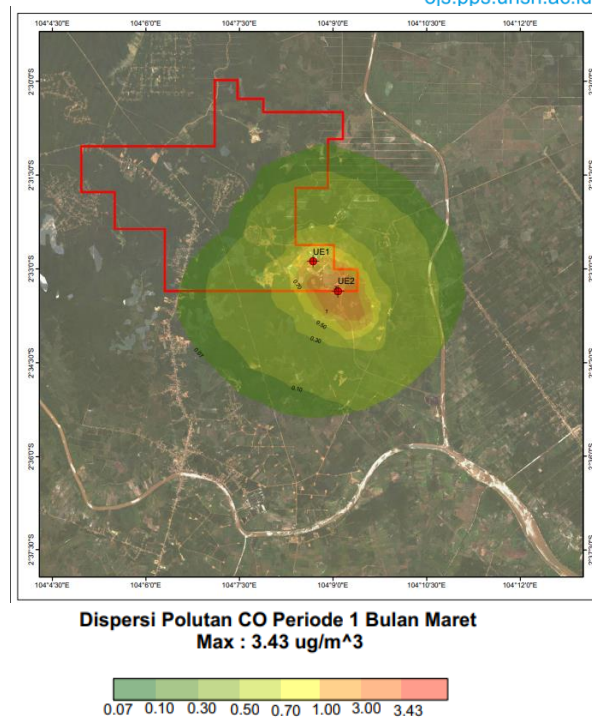


Figure 4. Lowest CO Pollutant Dispersion

The emission air dispersion pattern generated by AERMOD modeling depicts the dominating directions to the northwest and southeast based on Figure 4. The predominant wind direction from December 2021 to March 2022 is northwest, with wind speeds between 1.29 and 1.72 m/s. While the wind direction is toward the Southeast and the wind speeds are between 1.25 and 1.61 m/s within a radius of 5,000 meters from May to September 2022, the CO parameter pollutant emission has the highest value of 3.43 $\mu\text{g}/\text{m}^3$.

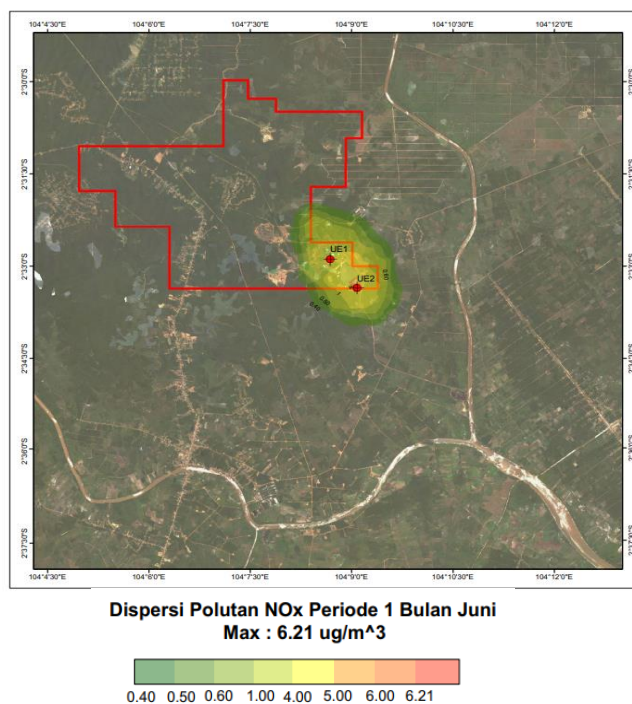


Figure 5. Highest NOx Pollutant Dispersion

Analysis was done for a month using the AERMOD modeling application, using the findings of emission measurements, topography data, and wind data models shown in Figure 5. The average pollutant dispersion modeling results for one month reveal that NOx levels are far below the quality limit; the peak NOx value for one month was $62.1 \mu\text{q}/\text{m}^3$. According to [15], a number of factors, such as the engine performance factor of the emission source, the weather in the affected area, and the presence of other activities, will significantly impact the concentration of pollutants exhaled from a specific emission source.

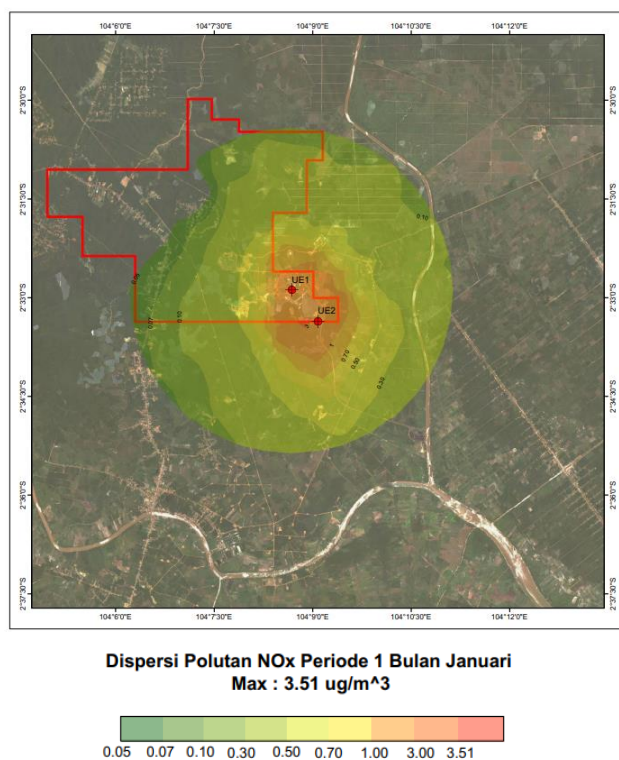


Figure 6. Lowest NOx Pollutant Dispersion

According to [13], a poor combustion process will cause residual combustion in the form of NOx to accumulate, causing the combustion process to be released directly into the air. This is influenced by two factors, namely the generator's condition and the materials' quality. Based on the results of Figure 6, it depends on these two factors. According to the simulation, it produces $3.51 \mu\text{q}/\text{m}^3$ of pollutants in January.

4. Conclusion

Based on the research that has been carried out, several conclusions are obtained as follows: Based on AERMOD modeling, the distribution pattern of air emissions shows the dominant directions are northwest and southeast. The dominant wind direction from December 2021 to March 2022 is northwest, with wind speeds between 1.29 and 1.72 m/s. In contrast, wind direction and wind speed ranged from 1.25 to 1.61 m/s from May to September 2022. The CO emission parameter has a maximum value of 30.4

$\mu\text{q}/\text{m}^3$, and the NOx parameter has a maximum value of $62.1 \mu\text{q}/\text{m}^3$, within a radius of 5,000 m, while the CO emission parameter has a minimum value of 3.43 $\mu\text{q}/\text{m}^3$ and the NOx parameter has a maximum value of $3.51 \mu\text{q}/\text{m}^3$.

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