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Article

Analysis of Sulfur Dioxide (SO_2) Exhaust Gas Emission Distribution Patterns from Airport's Incinerators in East Java

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Abstract

The airport in this study is one of the airports in East Java that uses an incinerator to process its waste. Emissions generated by the incinerator will disperse in the area surrounding one of the airports in East Java. With the increasing interest of the public in air travel, activity at the airport also increases. This increase also impacts the amount of waste processed by the incinerator and the emissions produced, including Sulfur Dioxide (SO_2). The aim of this study is to analyze the dispersion of air pollutants using Aermod View modeling software with SO_2 parameters from environmental document data of the airport from January to June and from July to December generated by the incinerator stack. The model produces isopleths representing the dispersion of SO_2 emissions. The results of the SO_2 model still meet ambient air quality standards, as indicated in Appendix VII of Government Regulation Number 22 of 2021.

Keywords: Air dispersion, Airport, modeling, Aermod View, Emissions, Incinerator

1. Introduction

The aviation industry is an air transportation sector that focuses on providing highly efficient air transportation services. It plays a vital role in the air transportation system, particularly in Indonesia, which consists of numerous islands. Air transportation plays a crucial role in facilitating population mobility and ensuring smooth activities in the country. The industry has experienced rapid development, especially marked by a surge in the number of passengers and airlines since the regulation of the aviation industry [1].
With the increasing interest of the public in using air transportation services, activities in the operational area of one of the airports in East Java have also significantly increased, resulting in an increase in waste volume. The waste generated from airport activities is then processed using an incinerator. Some pollutant parameters emitted from the exhaust gases that have negative impacts on health include Total Suspended Particulate (TSP), Sulfur Dioxide (SO_2), Nitrogen Oxides (NOx), and Carbon Monoxide (CO) [2], [3].

Sulfur Dioxide (SO_2) is one form of sulfur oxide gas (SOx). This compound is readily soluble in water, has a distinctive odor, and is colorless. It is produced during the combustion of fossil fuels containing sulfur. High levels of SO_2 in the air are one of the main causes of acid rain. This occurs because sulfur from the combustion of fossil fuels reacts with oxygen, forming sulfur dioxide (SO_2) [4]. Sulfur can be found in most raw, unprocessed materials such as crude oil, coal, and ores

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containing metals like aluminum, copper, zinc, lead, and iron [5]. This gas can spread up to 1000 kilometers because its retention rate in the atmosphere is only a few days. This can lead to regional acid rain and even affect neighboring countries [6]. Exposure to high concentrations of Sulfur Dioxide (SO_2) gas can lead to health issues, including irritation of the eyes, mucous membranes, and respiratory tract. This occurs because when SO_2 reacts with water or mucus in the respiratory tract, compounds such as hydrogen sulfide, bisulfite, and sulfite can form, causing irritation [7], [8].

This research will focus on testing SO_2 parameters to understand how exhaust gas emissions will disperse into the ambient air around area of one of the airports in East Java. With the various risks posed by exposure to these gases, this becomes a crucial factor in the analysis of exhaust gas dispersion in the area. In this regard, air dispersion modeling is required to gain a deeper understanding of the spread patterns of SO_2 in the air environment around one of the airports in East Java. Several ambient air sampling points have been designated in the area of one of the airports in East Java to monitor air quality, providing an initial overview of the air environment in its vicinity.

This study aims to investigate the distribution of Sulfur Dioxide (SO2) emissions generated by the incinerator and the ambient air quality in the area surrounding one of the airports in East Java. The emission distribution will be analyzed using Aermod View software, including dispersion range and influencing factors. The concentration values of these parameters will also be compared with the ambient air quality standards according to Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII.

2. Material and Method

The data to be inputted into the model are derived from the results of emission quality testing of thermal processing activities obtained from the environmental documents of one of airports in East Java in 2023, as well as local meteorological data during the same period. The emission load test results (mg/Nm^3) from the laboratory are converted into emission rates (g/s) to be used as input data in the modeling. Subsequently, meteorological and topographical data are obtained from sources such as the *power.larc.nasa.gov* website and Geographic Information Systems (GIS). Recorded meteorological information includes total cloud cover, temperature, humidity, pressure, wind direction, wind speed, and ceiling height, collected hourly for 24 hours. This data will be processed using Aermet View software to generate visualizations such as wind roses reflecting wind direction and speed over monthly or yearly time periods.

The emission test data generated by the incinerator are the measurements of exhaust gas emissions from two incinerator stacks located in the area of one of the airports in East Java. Some of the data collected include the concentration of Sulfur Dioxide (SO2). The measurement results are displayed in the following table.

Table 1. Laboratory Test Results of Incinerator Exhaust Gas Emissions

Para meter	Periods	Analysis Result		Maxi mum Level	Units
		Stack 1	Stack 2		
SO_2	Semester I	2,6	2,6	210	Mg/ Nm^3
	Semester II	<2,62	<2,62		

3. Results and Discussion

3.1. Wind Direction and Speed

The initial meteorological data analyzed is the wind direction and speed with the aim of understanding the influence of wind patterns on air dispersion. Changes in pollution levels in an area can be influenced by unpredictable wind patterns [9]. The analysis results are represented in the form of a graph called a wind rose using Aermet View software. This analysis is conducted for two periods: Semester I (January - June) and Semester II (July - December) Below are the surface wind pattern analysis results in the form of a wind rose.

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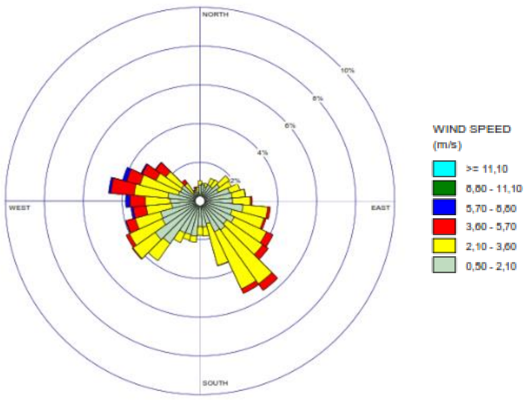

Fig. 1. Wind rose Semester I

In Semester I, or from January to June, the wind direction is predominantly from the west to the east and southeast to northwest. The average wind speed during this period is 2.14 m/s, with a calm winds frequency of 1.68%. This wind dispersion pattern from two opposite directions occurs due to seasonal changes. From January to March, there is a period of westerly monsoon, where the wind blows from the west to the east. Meanwhile, in June, it enters the period of easterly monsoon, where the wind blows from the northern hemisphere (Asia) towards the southern hemisphere (Australia). As a result, a wind dispersion pattern from two different directions is formed [10]–[12].

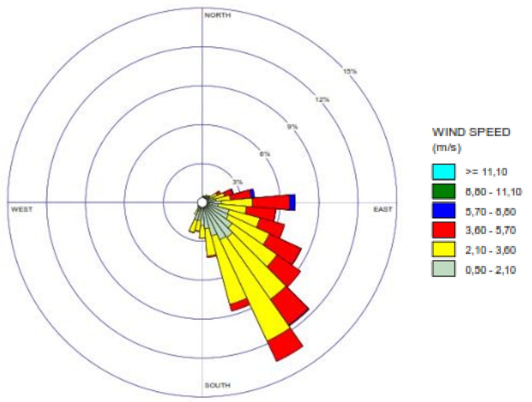

Fig. 2. Wind rose Semester II

In Semester II, or from June to December, the average wind speed is 2.56 m/s, with a calm winds frequency of 1.47%. The wind dispersion pattern during this period is predominantly towards the northern part of the Earth. This is due to the easterly monsoon period and the transition from the easterly to westerly monsoon. During this period, the dominant winds blow from the Pacific Ocean to the Indian Ocean [10]–[12].

3.2. Emission Dispersion Model Results

The results obtained are then modeled using AERMOD software to determine the dispersion pattern of exhaust gas emissions generated by the incinerator boiler. Based on Government Regulation Number 22 of 2021, Annex VII concerning Ambient Air Quality Standards, the Sulfur Dioxide (SO_2) parameter will be modeled at three measurement times: 1 hour, 24 hours, and 1 year. The results of the modeling are as follows.

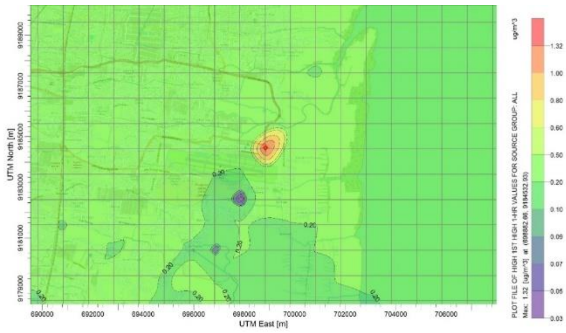

Fig. 3. Distribution of SO_2 emissions for 1 hour in semester I

Based on the analysis of the SO_2 emission dispersion modeling over a one-hour period in Semester I, it is observed that the pollutant concentrations range between 1.00 and 0.03 μg/m^3. These emissions have the potential to disperse northeastward within a distance of less than 1 kilometer from the highest concentration point, which is 1.00 μg/m^3, decreasing to a concentration of 0.50 μg/m^3. This area is known to be farmland and is located far from residential settlements. The pollutant concentration gradually decreases to 0.20 μg/m^3 at distances greater than 10 kilometers from the emission source. Low concentrations, ranging from 0.03 to 0.07 μg/m^3, are also recorded at distances of 2 kilometers and 4 kilometers from the source point. The concentration values from the dispersion model testing of this pollutant still meet the ambient air quality standards for SO_2 as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII, which is 150 μg/m^3.

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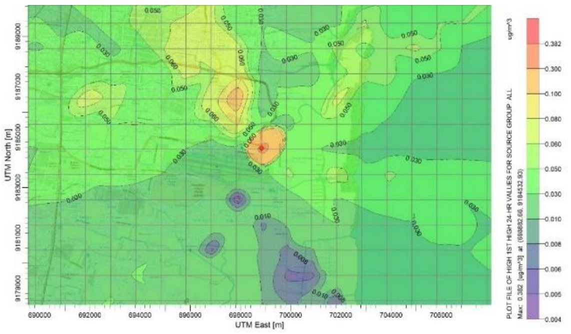

Fig. 4. Distribution of SO_2 emissions for 24 hours in semester I

In the 24-hour SO_2 emission dispersion modeling during the first semester, it was observed that the pollutant spread from the emission source reached a radius of 1 kilometer to the northeast, with concentrations ranging from 0.300 μg/m³ to 0.05 μg/m³. At a distance of 3 kilometers from the emission source, there is a dispersion point with a concentration of 0.100 μg/m³, which spreads up to 4 kilometers from that point, with the concentration decreasing to 0.06 μg/m³. The dispersion concentration continues to decrease until it reaches a value of 0.004 μg/m³, with the dispersion direction heading towards the industrial area to the north of one of the airports in East Java. The concentration values from this pollutant dispersion model test still meet the ambient air quality standards for SO_2 as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII, which is 75 μg/m3.

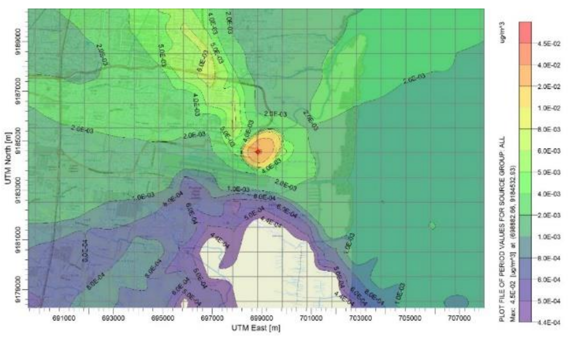

Fig. 5. Distribution of SO_2 emissions during 1 period in semester I

The model results show that the concentration of pollutant dispersion can reach 0.040 μg/m³ over a period in Semester I. At a distance of 1 kilometer from the emission source, there is a dispersion with the highest concentration of 0.040 μg/m³, which then decreases to 0.004 μg/m³. Furthermore, at a distance of 3 kilometers from the emission source, there is a dispersion point with a concentration of 0.006 μg/m³, which then spreads up to 2 kilometers from that point, with the dispersion direction heading northwest, where the area comprises industrial zones and residential areas. The concentration values from this pollutant dispersion model test still meet the ambient air quality standards for SO_2 as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII, which is 45 μg/m³.

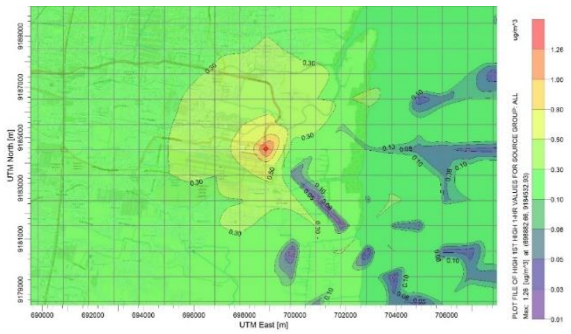

Fig. 6. Distribution of SO_2 emissions for 1 hour in semester II

In the modeling results of SO_2 emissions over 1 hour in Semester II, pollutant concentrations range between 1.00 and 0.01 μg/m³. The analysis shows that SO_2 emissions can spread northwestward within a distance of less than one kilometer from the highest concentration point of 1.00 μg/m³, decreasing to 0.80 μg/m³. The concentration further decreases to 0.50 μg/m³ within 1 kilometer from the emission source, and at 4 kilometers, the pollutant dispersion concentration decreases to 0.30 μg/m³. The pollutant dispersion is directed towards industrial areas, farmland, and parts of one of the airports in East Java, with concentrations continuously decreasing to 0.01 μg/m³. The concentration values from this pollutant dispersion model test still meet the ambient air quality standards for SO_2 as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII, which is 150 μg/m³.

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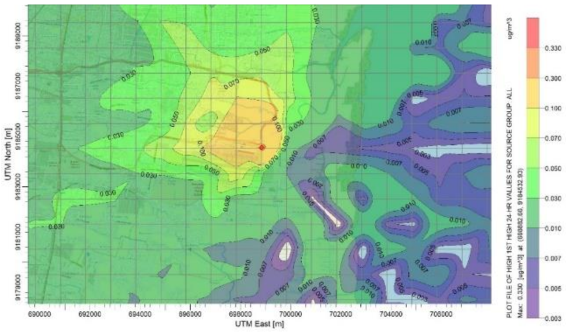

Fig. 7. Distribution of SO_2 emissions for 24 hours in semester II

The 24-hour SO_2 dispersion in Semester II resulted in concentrations ranging from 0.300 μg/m^3 to 0.003 μg/m^3. Within the initial 2 kilometers, the pollutant concentration was 0.30 μg/m^3, which then decreased to 0.10 μg/m^3. The concentration further decreased to 0.07 μg/m^3 at a distance of 4 kilometers from the emission source, and it continued to decrease to 0.003 μg/m^3. The dispersion pattern from the model is uneven due to the influence of wind direction and the area's topography. The SO_2 dispersion is directed northwestward, encompassing parts of the airport, industrial areas, and farmland. The concentration values from this pollutant dispersion model test still meet the ambient air quality standards for SO_2 as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII, which is 75 μg/m^3.

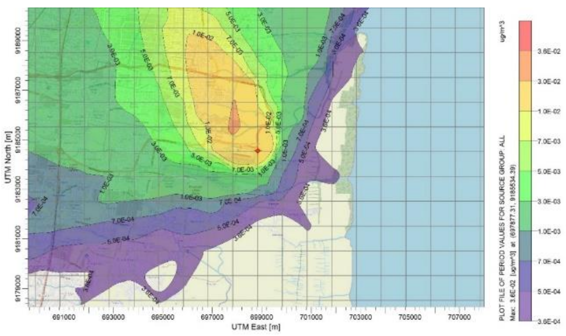

Fig. 8. Distribution of SO_2 emissions during 1 period in semester II

The results from the SO_2 dispersion modeling over one period in Semester II show concentrations ranging from 0.030 μg/m^3 to 0.00036 μg/m^3. At a distance of 1 kilometer from the emission source, there is an isopleth with a concentration value of 0.03 μg/m^3. The dispersion then heads northwest, spreading up to 3 kilometers with a concentration of 0.01 μg/m^3. Over the next kilometer, the concentration decreases to 0.007 μg/m^3, and as the distance from the pollutant source increases, the concentration continues to decrease, reaching 0.00036 μg/m^3. This SO_2 dispersion impacts parts of the airport, industrial areas, farmland, and residential areas. The concentration values still meet the ambient air quality standards for SO_2 of 45 μg/m^3, as stipulated in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VII.

4. Conclusions

The dispersion patterns generated by the Aermod View model show that in Semester I (January-June), the dispersion is predominantly towards the Northeast, while in Semester II (July-December), the dispersion is predominantly towards the Northwest. This non-uniformity is evident in the dispersion pattern of Sulfur Dioxide (SO_2) emissions from the incinerator in the vicinity of one of the airports in East Java. The isopleth results of the model indicate that Sulfur Dioxide (SO_2) is not uniformly dispersed from the pollutant source. This is influenced by wind direction, topography, and settlement patterns, resulting in uneven dispersion.

Looking at the concentration values of SO_2 modeled by Aermod View, none of these values exceed the ambient air quality standards set by Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. Therefore, the ambient air around of one of the airports in East Java is still safe for human consumption. However, it is necessary to continue increasing greenery in the areas around of one of the airports in East Java to reduce the spread of pollutants and ensure cleaner air.

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