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Effect of Mixing Height on Box Model Calculation in Sulfur Dioxide Dispersion Modeling of Oil and Gas Industries

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Abstract

This study was conducted to determine the effect of height in the calculation of box model dispersion modeling. The experimental method was conducted using sample data of sulfur dioxide exhaust emissions produced by the oil and gas industry. The samples were obtained from an oil and gas company that produces sulfur dioxide emissions. There are two types of data obtained, namely hourly emission data and daily emission data generated by the industry with the amount of data obtained for 360 days. The results showed that the mixing height used in the box model formulation affects the results of the calculation. The optimal mixing height obtained from the study was 75 meters where all sample data used in the calculation showed that there were only 3.5% or 11 samples that did not meet the ambient air quality standards. The results also showed that the higher the mixing height used, the lower the emission of sulfur dioxide emission dispersion modeling calculation results. While calculations with lower mixing height will produce results that are inversely proportional to the concentration of sulfur dioxide emissions, the concentration of sulfur dioxide emissions produced will be higher. Therefore, sulfur dioxide dispersion modeling using a box model can be an alternative in determining the concentration of sulfur dioxide emissions produced.

Keywords: *Sulfur Dioxide, Dispersion Modeling, Box Model, Mixing Height, Oil and Gas*

1. INTRODUCTION

Oil and gas are natural resources that are used as energy in daily activities, especially in industry. Some oil and gas commodities in Indonesia can penetrate the global export market. In meeting these needs, many oil and gas companies were established in Indonesia Oil and gas (oil and gas) is also one of the most needed energy-producing natural resources in human life at this time. This natural resource cannot be separated from daily activities because it provides a number of benefits. In Indonesia, oil and gas energy is still the mainstay of the economy, both as a foreign exchange earner and supplier of domestic energy needs. Therefore, the presence of oil and gas is very important for life in Indonesia.

Oil and gas industry activities also produce gas emissions, liquid waste, and solid waste. solid waste. Gas emissions (pollutants) produced generally include VOCs (volatile organic compounds), carbon monoxide (CO), sulfur oxides (SO), nitrogen oxides (NO), particulates, ammonia (NH), hydrogen sulfide (H2S), metals, acidic materials, and other toxic organic components (Cheremisinov, 2002). Monitoring of emissions from activities and ambient air quality around the location of industrial activities can be done by modeling, determining the amount of concentration of these activities based on meteorological conditions. The box model is used to estimate the average concentration of pollutants in an area that is assumed to be a box where emission sources are evenly distributed on the bottom surface of the box. This model considers an area or city as a box. Inside the box there are activities that produce emissions. This model considers meteorological factors such as wind speed, as well as mixing height (Astuti, 2017). This research will analyze the load of emission concentration in the form of Sulfur Dioxide gas emissions from the stack of an oil and gas industry using the box model method.

This research aims to investigate how variations in air mixing height can affect the calculation results of the box model in SO2 dispersion modeling. By varying the air mixing height, this study can identify the effect between the air mixing height and SO2 distribution predicted by the box model. The results of this research can provide important insights in optimizing SO2 dispersion modeling, increasing prediction accuracy, and assisting decision making in managing emissions from the oil and gas industry.

2. MATERIAL AND METHODS

2.1 Materials

For the research "Effect of mixing height on box model calculation in sulfur dioxide dispersion modeling of oil and gas industries", some materials needed are SO_2 pollutant data, meteorological data (wind speed), open air software applications and box model.

2.2 Methods

2.2.1 Data Collecting (CEMS)

Collecting sulfur dioxide (SO2) emissions data from the oil and gas industry. This data includes SO2 emissions from the stack. In addition, it is also necessary to collect meteorological data such as wind speed direction relevant to the study area. Continuous emission monitoring system or continuous emission monitoring system (CEMS) is installed on the stack to monitor several emission parameters that are important in evaluating the performance of combustion efficiency as part of air pollution control air pollution control. The CEMS sampling method applied is in stack dilution xxtractive (Schwartz et al., 1994). Here is an outline of how the CEMS would work using the stack dilution extractive method:

- Sampling Probe Installation: A sampling probe is installed in the exhaust stack at a suitable location downstream of the emission source. The probe is designed to extract a representative sample of the exhaust gas for analysis.
- Dilution Air Injection: A controlled flow of clean dilution air is injected into the stack through a separate inlet, either upstream or downstream of the sampling probe. The dilution air helps to lower the pollutant concentrations in the sample, making it more suitable for analysis and measurement.
- Sample Extraction: The sampling probe extracts a portion of the diluted exhaust gas and directs it to the CEMS system. The probe may include features such as heated lines or filters to remove moisture or particulate matter that could interfere with the measurement.
- Gas Conditioning: The extracted sample undergoes gas conditioning to prepare it for analysis. This may involve processes such as temperature and pressure adjustment, moisture removal, and filtering to ensure that the gas sample meets the requirements of the measurement instruments.
- Analysis and Measurement: The conditioned gas sample is then analyzed using appropriate measurement techniques based on the specific pollutants of interest. These techniques may include spectrometry, gas chromatography, or other

analytical methods. The instruments measure the concentration or mass of the pollutants in the gas sample.
- Data Acquisition and Processing: The measurement data from the CEMS instruments are acquired and processed by a central data acquisition system. The system collects, stores, and organizes the data for further analysis and reporting. It performs necessary calculations and conversions to standard units for compliance reporting.
- Calibration and Quality Assurance: Regular calibration of the CEMS instruments and quality assurance checks are essential to ensure accurate and reliable measurements. Calibration involves comparing the instrument readings with known calibration standards, while quality assurance procedures are performed to verify the overall performance and accuracy of the CEMS.
- Data Reporting and Compliance: The collected measurement data, along with compliance-related information, is recorded and reported to regulatory agencies as required. Periodic reports are generated, detailing emission levels, compliance status, and other relevant information. These reports are submitted to the appropriate authorities for compliance assessment and regulatory purposes.

2.2.2 Air Mixing Height Determination

To determine the Mixing Height, it will be varied by assuming the addition of the Tailgas Thermal Oxidizer (TTO) stack height. The stack height of the Tailgas Thermal Oxidizer unit then for the assumed height of the box will be added and varied by 10 meters referring to the head of the environmental impact control agency, Number: KEP-205 / BAPEDAL / 07/1996 concerning technical guidelines for controlling air pollution from immobile sources to get the concentration of pollutant distribution through its height. So that the Mixing Height will get 45 meters, 55 meters, 65 meters, and 75 meters.

2.2.3 Box Model

A box model is a mathematical model used to simulate and analyze the dispersion of pollutants in a specific area or "box." It divides the study area into discrete boxes or cells and tracks the movement and transformation of pollutants within those boxes. Here's a general overview of how a box model works:

- Define the Study Area: Determine the geographical boundaries of the study area and divide it into a grid or network of boxes or cells. The size and number of boxes depend on the spatial resolution required for the analysis.
- Specify Emission Sources: Identify and quantify the emission sources within the study area. This includes industrial sources, vehicular emissions, and other relevant sources. The emissions are typically characterized by their release rates and pollutant concentrations.
- Define Meteorological Inputs: Obtain meteorological data for the study area, such as wind speed and wind direction These inputs are crucial for simulating the transport and dispersion of pollutants.
- Transport and Dispersion Modeling: Simulate the movement of pollutants within the box model using transport and dispersion algorithms. These algorithms consider factors like wind patterns, atmospheric stability, and the physical characteristics of the study area. The model calculates the advection (horizontal movement) and diffusion (vertical and horizontal spreading) of pollutants within each box.

- Chemical Reactions and Transformation: Incorporate chemical reactions and transformation processes if relevant to the pollutants being modeled. For example, if studying the dispersion of air pollutants, reactions such as photochemical reactions or pollutant decay may be included in the model.
- Boundary Conditions and Deposition: Set boundary conditions for the edges of the study area, considering the inflow and outflow of air or pollutants at the boundaries. Additionally, consider the deposition processes, such as dry deposition or wet deposition, which affect the removal of pollutants from the atmosphere.
- Output and Analysis: Analyze the results of the model simulation, including pollutant concentrations, spatial distribution, and temporal patterns. Visualize the output using maps, charts, or graphs to better understand the dispersion behavior of pollutants within the study area.

The following below is the formula for the Box Model calculation model that will be tested by the author to calculate pollutant distribution.

$$C = \frac{Q\ (^{mg}/_{det})}{L\ (m)\ x\ H\ (m)\ x\ u\ (^{m}/_{det})} \tag{1}$$

Description:
Q = Emission Load
L = Length
H = Mixing Height
u = Wind Speed

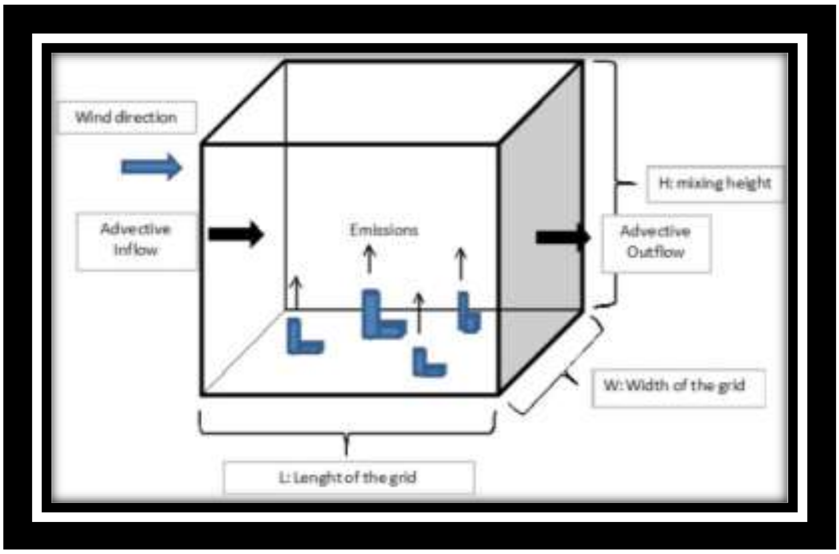

Figure 2. 1 Illustration of the box model formula

3. RESULTS AND DISCUSSION

3.1 Windrose Analysis at the Research Site

Sulfur dioxide (SO2) pollutant source analysis at the research site was conducted based on a combination of the rainy and dry seasons. There are two windrose diagram images formed, namely during the rainy season (October, November, December, January, February, March) and the dry season (April, May, June, July, August, September). Windrose shows the dominant wind direction and the direction of the dominant wind speed in a certain period, therefore it can show how far and in what direction pollutants can potentially be dispersed from the source to the environment. This diagram shows how wind speed and wind direction conditions vary over a period of time including during the dry and wet seasons on the basis of eight wind directions (every 45°). As for the windrose analysis in each season, among others as follows:

3.1.1 Windrose in the Rainy Season

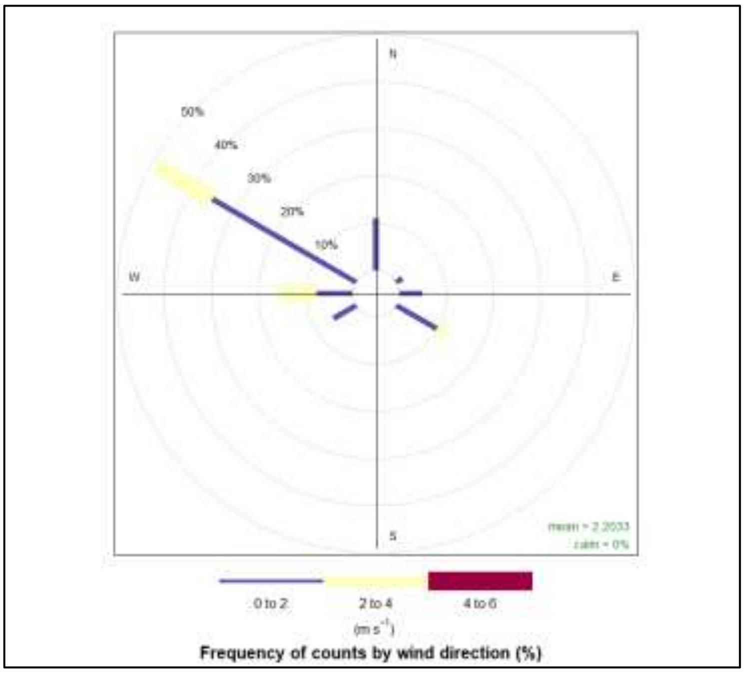

Figure 3. 1 Rainy season windrose chart

The windrose diagram in Figure 3.1 shows during the rainy season (October, November, December, January, February, March). The gray circles around the paddles represent the frequency of wind direction that occurs during October 2021 to March 2021. The Purple, Yellow and Red paddles represent the range of wind speeds at a given wind direction frequency. The information in the lower right corner of the diagram in Figure 3.1 that reads "mean = 2.2033" and "calm = 0%" means that the average wind speed in the rainy season (October, November, December, January, February, March) in the study area occurs at 2.2033 meters/second with a calm wind speed frequency of 0%. The frequency of calm wind speed describes the condition when the wind speed is calm (0 meters/second). Furthermore, Figure 3.1 shows that the dominant wind direction in the study area comes from the northwest with a frequency of 10-50%, then 10-20% comes from the west, the direction is indicated by the west monsoon winds and sea breezes that occur in the study area.Sulfur Dioxide (SO2) Concentration Pattern in

3.1.2 Windrose in the Dry Season

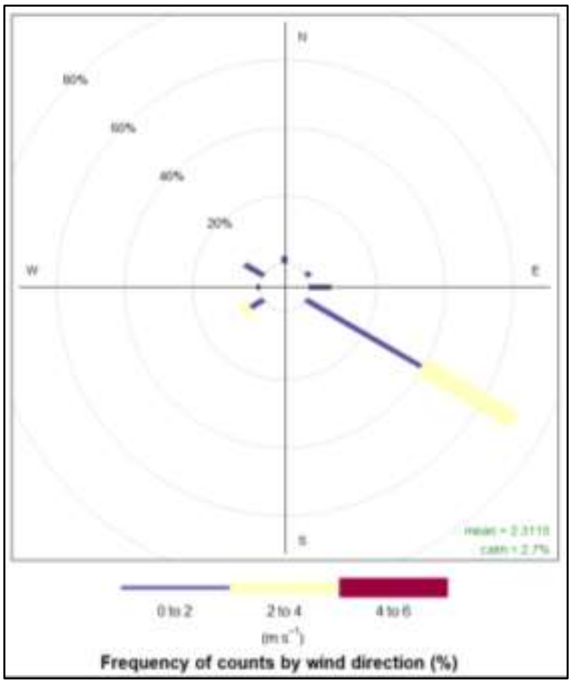

Figure 3. 2 Dry season windrose chart

Figure 3.2 is a windrose diagram formed during the dry season (April, May, June, July, August, September). The gray circles around the paddles represent the frequency of wind direction that occurs during April 2021 to November 2021. The Purple, Yellow and Red paddles show the range of wind speeds at a given wind direction frequency. There is a "mean" information in the lower right corner of the diagram Figure 3.2 which reads "mean = 2.3115" and "calm = 2.7%" which means that the average wind speed in the dry season (April, May, June, July, August, September) in the study area occurs at 2.3115 meters / second with a calm wind speed frequency of 2.7%. The frequency of calm wind speed will describe the conditions when the wind speed is calm (0 meters / second) which in this case the wind speed is very calm from all data during the dry season (April, May, June, July, August, September). In addition, Figure 3.2 also shows the dominant wind direction in the study area during the dry season (April, May, June, July, August, September). comes from the southeast with a frequency of 10-80%, the direction is indicated by the east monsoon winds and sea breezes that occur in the study area.

3.2 Effect of Mixing Height on SO_2 Concentration

In this study, the Box Model calculation is carried out as usual to determine the concentration of pollutant load accumulated in the box that is assumed in the calculation, but the height (H) of the box or Mixing Height will be varied considering the dimensions of the box that is assumed to change When the Mixing Height of the box changes, the analysis of the resulting emission load will also have different results. The calculation is done by entering the emission load that has been obtained from the previous calculation into the Box Model formula. Variations are made to see the maximum sulfur dioxide pollutant emission load in the box in the work area. After obtaining the emission load, the next step is to enter it in the Box Model calculation.

3.2.1 Calculation of Box Model with a Height of 45 Meters

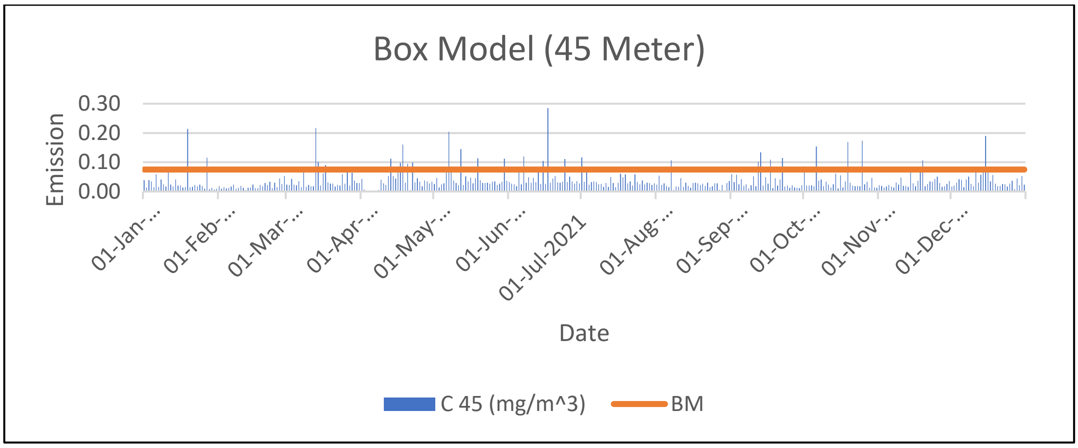

Figure 3. 3 Calculation of 45 meter height box model

Figure 3.3 shows the graph of the results of the Box Model calculation with a height variation of 45 meters. The blue line represents the concentration of Sulfur Dioxide (SO2) pollutants contained in the modeled box, while the orange line is the ambient air quality standard of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. On the graph there are still Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. There are 37 samples out of 360 samples that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. This means that at a Box Model height of 45 meters there are still 10.7% of Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021.

3.2.2 Calculation of Box Model with a Height of 55 Meters

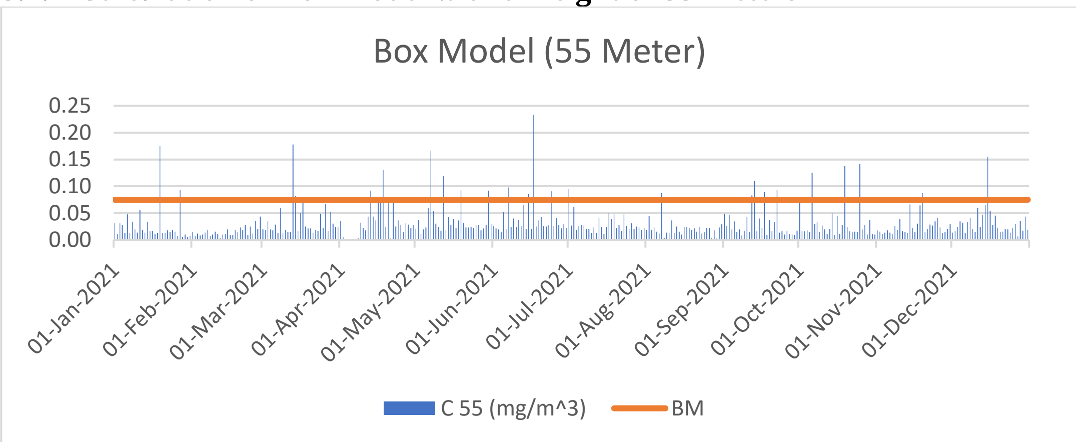

Figure 3. 4 Calculation of 55 meter height box model

Figure 3.4 shows the graph of the results of the Box Model calculation with a height variation of 55 meters. The blue line represents the concentration of Sulfur Dioxide (SO2) pollutants contained in the modeled box, while the orange line is the ambient air quality standard of the Government Regulation of the Republic of

Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. On the graph there are still Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. There are 28 samples out of 360 samples that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. This means that at a Box Model height of 55 meters there are still 7.7% of Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021.

3.2.3 Calculation of Box Model with a Height of 65 Meters

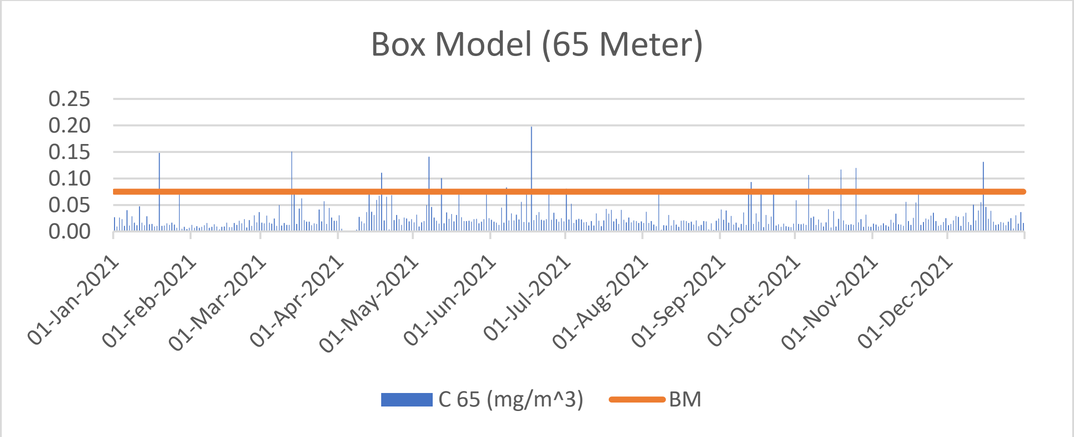

Figure 3. 5 Calculation of 65 meter height box model

Figure 3.5 shows the graph of the results of the Box Model calculation with a height variation of 65 meters. The blue line represents the concentration of Sulfur Dioxide (SO2) pollutants contained in the modeled box, while the orange line is the ambient air quality standard of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. On the graph there are still Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. There are 20 samples out of 360 samples that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. This means that at a Box Model height of 65 meters there are still 5.5% of Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021.

3.2.4 Calculation of Box Model with a Height of 75 Meters

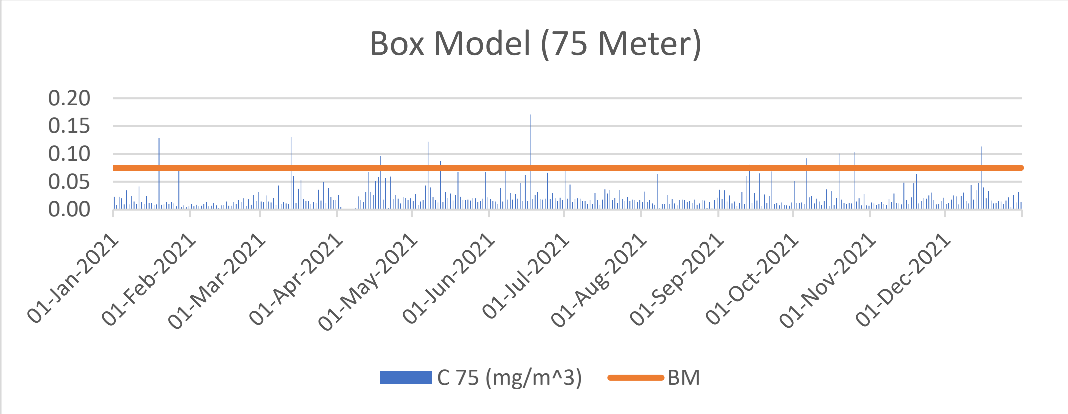

Figure 3. 6 Calculation of 75 meter height box model

Figure 3.6 shows the graph of the results of the Box Model calculation with a height variation of 75 meters. The blue line represents the concentration of Sulfur Dioxide (SO2) pollutants contained in the modeled box, while the orange line is the ambient air quality standard of Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. On the graph there are still Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. There are 11 samples out of 360 samples that exceed the ambient air quality standards of the Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. This means that at a Box Model height of 75 meters there are still 3.5% of Sulfur Dioxide (SO2) pollutants that exceed the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021.

After knowing the concentration of Sulfur Dioxide (SO2) pollutants in each variation of Box Model modeling by varying the height or Mixing Height, we can see the accumulation of all data samples for 1 full year in 2021 showing the concentration of the distribution of Sulfur Dioxide (SO2) pollutants in the work area. The graph of all data samples is presented in Figure 3.7

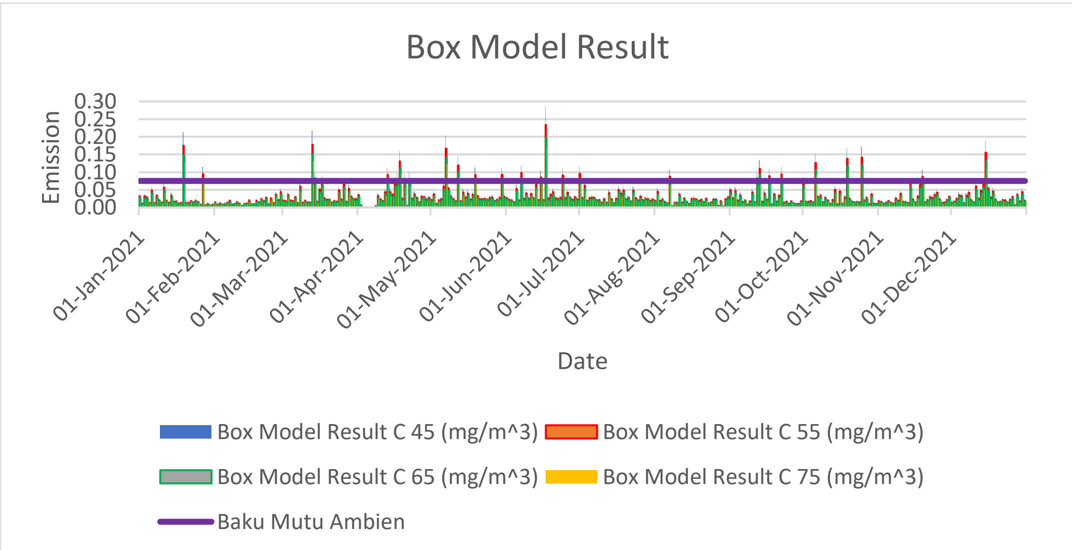

Figure 3. 7 Box Model calculation result graph

Figure 3.7 shows the graph of the results of the calculation of the emission load using the Box Model formula, it can be seen that there are lines of different colors, the blue color displays the results of the box calculation with a height of 45 meters, the red color displays the results of the box calculation with a height of 55 meters, the green color displays the results of the box calculation with a height of 65 meters, the yellow color displays the results of the box calculation with a height of 75 meters, and the purple color is the ambient air quality standard of the Government Regulation of the Republic of Indonesia Number 22 of 2021 of 0.075 mg/m3. The emissions in the simulated box around the work area show the use of Mixing Height or the lower height in the box, it will strengthen the concentration in the box itself. Then the total sample data from this modeling variation is 1440 data with total data that does not meet the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021 is 96 sample data, so there are 6.7% sample data that still does not meet the ambient air quality standards of the Government of the Republic of Indonesia Regulation Number 22 of 2021. When Sulfur Dioxide (SO2) pollutants are dispersed, a large open space is needed to ensure that pollutants are well distributed and do not collect at one point, the larger and wider the simulated box, the smaller the concentration of Sulfur Dioxide (SO2) pollutant emissions.

4. CONCLUSION

In the research on "Effect of mixing height on box model calculation in sulfur dioxide dispersion modeling of oil and gas industries," it was found that mixing height has a significant influence on box model calculation in sulfur dioxide (SO2) dispersion modeling of the oil and gas industry. Variations in mixing height affect the pattern and distribution of SO2 dispersion. Higher air mixture height can lead to better mixing and dispersion, thus reducing the SO2 concentration around the emission source. Conversely, a low air mixture height can lead to high SO2 concentrations in the region around the emission source. Accurate and representative air mixture height measurements and monitoring are essential in SO2 dispersion modeling. Precise data on air mixture height can help improve SO2 dispersion estimates and enable better decision-making regarding emissions management and environmental protection.

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