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Development of An Air Quality Model For Public Health Risk Analysis (Case Study of Dangku Village Special Coal Terminal, Muara Enim, South Sumatra)

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A B S T R A C T

Mining for coal is a human activity that can contribute to air pollution. Solar power generation using a generator to produce electricity is one of the activities that cause air pollution. Electricity is crucial for mining operations, particularly in terminals that transport coal by river or sea. This study aims to develop a model of air pollution caused by PT XYZ's solar generator in Dangku Village, Muara Enim, South Sumatra, in the form of patterns of distribution and concentration levels of NO2 and CO pollutants, as well as to assess the health risks to the local community. The modelling development method employs the AERMOD software by inputting air quality data, meteorology, the specifications of the existing 2-meter chimney, and topography. To achieve NO2 levels of 180 ug/m3 and CO levels of 18.2 ug/m3, the model results indicate that the chimney's height must be increased to 4 metres in order to meet the quality standard for NO2 and CO levels. Regarding the results of the analysis of the level of public health risk in the area, there is no significant difference between chimneys measuring 2 and 4 metres.

Kata kunci:

AERMOD
Polusi udara
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A B S T R A K

Penambangan batu bara merupakan kegiatan manusia yang dapat berkontribusi terhadap pencemaran udara. Pembangkit listrik tenaga surya dengan menggunakan genset untuk menghasilkan listrik merupakan salah satu kegiatan yang menimbulkan pencemaran udara. Listrik sangat penting untuk operasi pertambangan, terutama di terminal yang mengangkut batubara melalui sungai atau laut. Penelitian ini bertujuan untuk mengembangkan model pencemaran udara akibat pembangkit tenaga surya PT XYZ di Desa Dangku, Muara Enim, Sumatera Selatan, berupa pola sebaran dan tingkat konsentrasi polutan NO2 dan CO, serta mengkaji risiko kesehatannya. kepada masyarakat setempat. Metode pengembangan pemodelan menggunakan perangkat lunak AERMOD dengan memasukkan data kualitas udara, meteorologi, spesifikasi cerobong 2 meter eksisting, dan topografi. Untuk mencapai kadar NO2 sebesar 180 ug/m3 dan kadar CO sebesar 18,2 ug/m3, hasil model menunjukkan bahwa tinggi cerobong asap harus ditambah menjadi 4 meter agar memenuhi baku mutu kadar NO2 dan CO. Terkait hasil analisis tingkat risiko kesehatan masyarakat di wilayah tersebut, tidak ada perbedaan yang signifikan antara cerobong berukuran 2 dan 4 meter.

INTRODUCTION

Air pollution has evolved into a worldwide environmental issue of international concern. This is due to the fact that air pollution is one of the leading causes of death worldwide. In 2015, air pollution caused 6,4 million deaths, and by 2060, 6–9 million deaths were anticipated (Glencross, 2020).

Coal mining is a human activity that can contribute to air pollution (Setiawan, 2018). Using diesel-powered generators to meet the electricity demand is one of the mining activities that can cause emissions. Increased reliance on solar power plants raises concerns over the resulting exhaust emissions (Agarwal, 2022). Diesel generators are frequently used as prime movers and independent power sources in numerous applications due to their fuel efficiency, durability, and dependability (Goh, 2003).

Carbon dioxide (CO2), carbon monoxide (CO), and nitrogen oxides (NOx) are the most prevalent pollutants emitted by diesel-powered generators (Jakhrani, 2012). NOx are gaseous compounds in the atmosphere that are composed of nitric oxide, nitrogen dioxide, and other oxides (Hamra et al., 2015). One of the precursors to secondary pollutants in the form of ozone is nitrogen dioxide (NO2). In addition, NO2 is extremely hazardous to health because it can reduce lung function, cause shortness of breath, and even cause death (Suyono, 2014).

Carbon monoxide (CO) is an odourless gas found in the atmosphere. Low-level CO exposure can result in neurological changes, decreased activity, and an increase in hematocrit. At high concentrations, CO can alter the foetus. CO gas that enters the body can bind strongly with haemoglobin to form carboxyhemoglobin (COHb), which inhibits oxygen delivery and causes death (Aprilia, 2017). CO emissions can also lead to ozone layer depletion (O3), which can cause skin cancer (Setiawan et al., 2018).

Indonesia is one of the largest coal producers in the world. PT XYZ, located in Muara Enim, South Sumatra, is one of Indonesia's companies driving coal mining activities. By 2020, PT XYZ will produce 5 million metric tonnes of coal annually. In tandem with coal demand growth in 2020, the PT is increasing coal production by up to 10 million metric tonnes annually. A coal terminal was constructed in South Sumatra's Dangku Village, Empat Petulai Dangku District, Muara Enim Regency, to support increased coal production and facilitate river or sea transportation activities.

The operation of a specific coal terminal necessitates electricity facilities to support operational activities; therefore, 1 unit of a diesel generator with a capacity of 312.5 kVA is provided as a supporting facility but cannot be operated due to feasibility and permitting issues from the source of pollutant emissions produced by the diesel generator. Therefore, it is necessary to conduct simulations using modelling so that the generator can be put into operation immediately.

The AERMOD model is a steady-state model that assumes the Gaussian concentration distribution for the horizontal and vertical distribution of emissions (Ekojunarto, 2022). In addition to the distribution of emissions, AERMOD modelling can perform a risk assessment, i.e. the characterization of potential effects that can be harmful to human health due to exposure to environmental hazards.

According to PP No. 22 of 2021 Appendix VII, the operational solar generator activities of PT XYZ can only be approved if the isopleth contribution of the action does not cause a significant reduction in air quality because it does not exceed the ambient air quality standard.

This research was conducted to develop a model for solar generators at PT XYZ's specific coal terminal, so that the NO2 and CO pollutants they produce do not exceed government-mandated quality standards and do not pose a health risk to the community.

METHOD

Research Design

The research design utilised a quantitative descriptive method consisting of data collection, field data processing, and a mapping method that was software-processed to see patterns of distribution of NO2 and CO pollutant emissions, as well as an analysis of health risks to the community surrounding the study site.

Time and Place of Research

The research was conducted in February–December 2022. This research was conducted at the National University using the required data from a particular coal terminal in Dangku Village, Empat Petulai Dangku District, Muara Enim Regency, South Sumatra Province. Air quality data is obtained from monitoring locations at two areas where special terminal activities are estimated to contribute the most emissions. Point one is the position of the diesel generator chimney. Colon is the entrance to the chimney location, at a radius of 5 kilometres. The location of the modelling development field is shown in Figure 1.

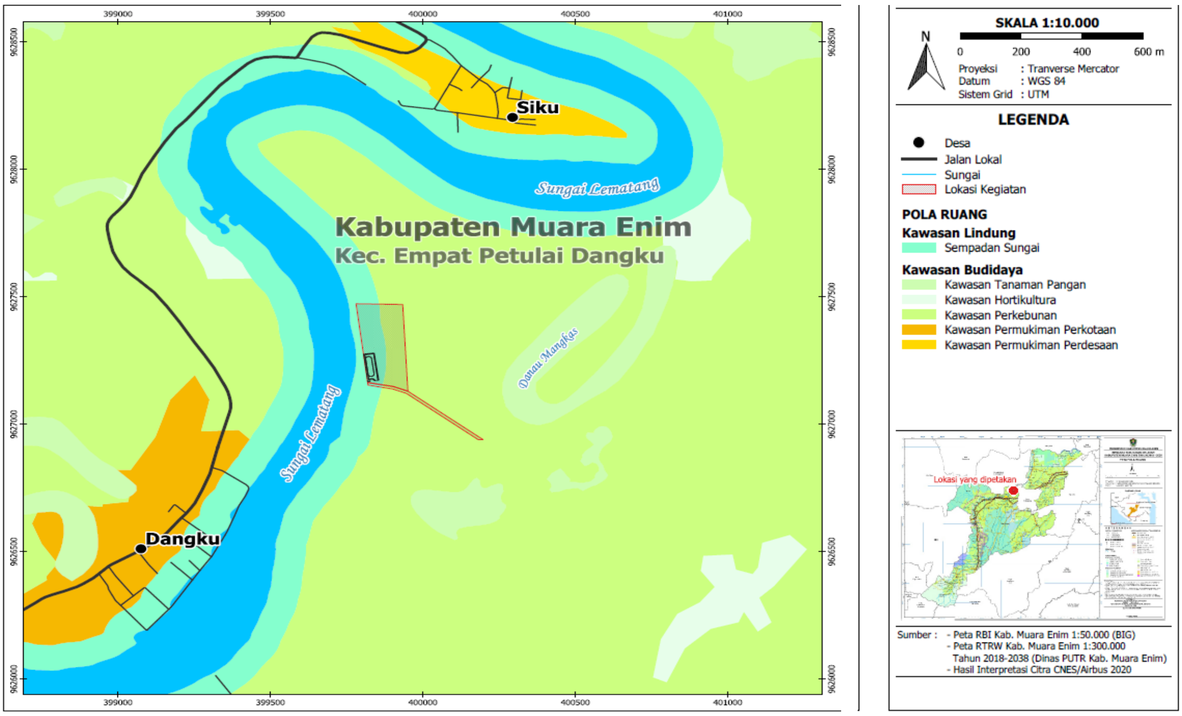

Figure 1. Air monitoring location for PT XYZ's special coal termina

Tools and Materials

Stationery, laptops, data storage devices, AERMOD software, WRPLOT View for visualising windroses, and secondary data are used for data collection (Ekojunarto, 2022). Secondary data consist of emission measurement results (NO2 and CO), chimney and building specifications, meteorological data (wind speed, wind direction, solar radiation, cloud cover, dry bulb temperature, lowest cloud height, rainfall, pressure, and humidity), and upper air format data. Free Space Loss (FSL) data from the National Oceanic and Atmospheric Administration (NOAA) and the elevation map of the research area from WEBGIS, in addition to public health data from the Empat Petulai Dangku District Health Center.

Emission Dispersion Modeling

To determine the distribution model of NO2 and CO emissions in the region surrounding the specific coal terminal and the level of risk to public health using the existing 2 m chimney and the chimney that must be modified, wind speed and direction data are processed with WRPLOT to determine the dominant wind direction, or windrose. Meteorological data and upper air data are processed with AERMET View; emission rate data and elevation maps are processed with AERMOD View, which includes AERMAP for modelling and producing NO2 and CO emission distribution patterns.

AERMOD Model

AERMOD workflow can be seen in Figure 2.

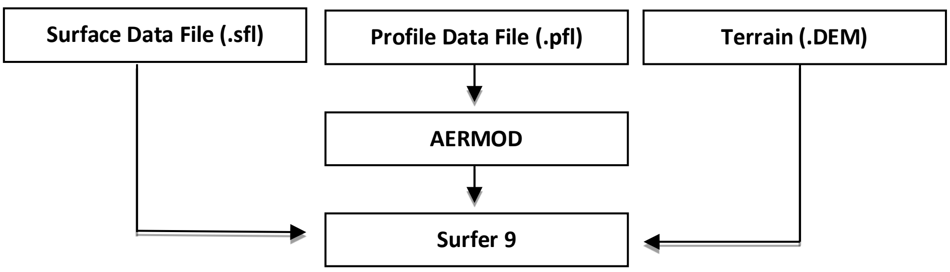

Figure 2. AERMOD workflow

Suppose you have processed surface and upper air data into an AERMET view. In that case, the next step is processing emission rate data, AERMET output results, and elevation images into an AERMET idea, which can be seen in Figure 3.

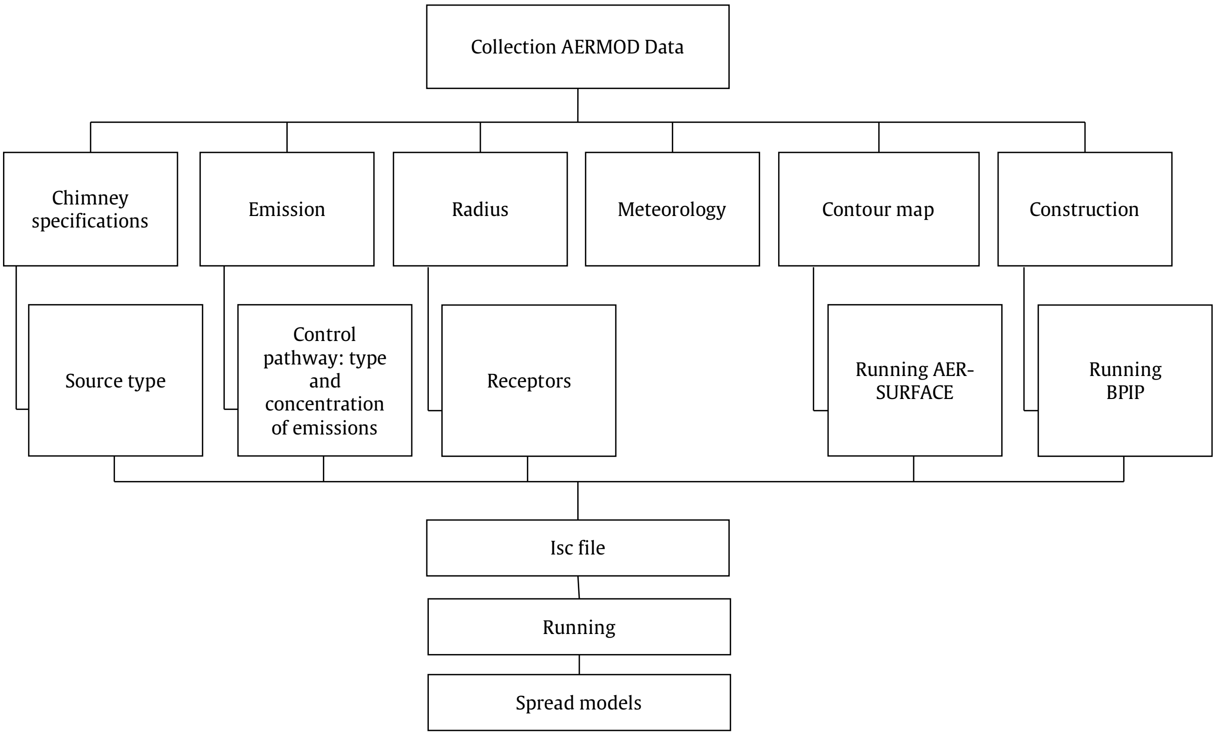

Figure 3. AERMOD workflow

Health Risk Level Analysis (RQ)

The level of risk is expressed in numbers without units, which is a calculation of the comparison between intake and a reference dose or concentration of a non-carcinogenic risk agent and can also be interpreted as safe or unsafe for a risk agent for organisms, systems, or sub-populations. Before carrying out a risk analysis, it is necessary to determine the characteristics of the risk, namely the RQ (risk quotient). RQ is calculated by comparing the values obtained from exposure or intake analysis and dose-response. The RQ value is used to assess the level of risk for non-carcinogenic effects. The story of risk is said to be safe if the RQ value is one and said to be unsafe if RQ > 1.

The following equation is used to find intake values and risk levels (RQ) from data on NO2 and CO concentrations in the air, anthropometric data, and job characteristics data:

$$I = \frac{C \ x \ R \ x \ t_E \ x \ f_E \ x \ D_t}{W_b \ x \ t_{avg}}$$

Information :

I	: Intake (mg/kg/day)
C	: Concentration NO_2, CO ambient air (mg/m^3)
R	: Inhalation rate (mg/m^3)
tE	: Exposure time (hours/day)
fE	: Exposure Frequency (day/year)
Dt	: Exposure duration (years)
Wb	: Weight (kg)
tavg	: Average time period

Meanwhile, to determine the risk characteristics (RQ), the formula is used:

$$RQ = \frac{I}{RfC}$$

Information:

RQ : NO2 and CO risk levels
I : Intake (mg/kg/day)
RfC : Reference Dose of NO2 and CO (mg/kg/day)

Table 1. Source characteristics and emission quality

Emission Source Code	Capacity (kVA)	Fuel	Diameter (m)	Exhaust Gas Speed (m/s)	Flow Rate (m3/s)	Emission Rate (g/s)		Information
						Nox	CO	
Jetty-1	312,5	Solar	0,125	9,974	0,1224	0,416	0,021	Operational

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RESULTS AND DISCUSSION

Calculation of Generated Emission Load

The emission load resulting from modeling is shown in Table 1. NO2 levels were 3,400 mg/nm3 and CO levels were 170 mg/nm3 based on data gathered from chimney specifications and air quality monitoring at PT XYZ. The annual amount of NO2 produced is 13,124 tonnes. The NO2 emission rate from the generator is 0.021 g/s, while the CO emission rate is 0.41 g/s. The results of the emission rate values are then analysed with the emission distribution outputs of the AERMOD software. The modelling development also produced recommendations for converting a 2-meter chimney to a 4-meter chimney. This is associated with the 2 m chimney's isopleth contribution of NO2 and CO.

Differences in the Modeling Results of NO2 and CO Contributions using 2 m and 4 m chimneys

The results of the isopleth distribution modelling of the NO2 pollutant contribution using 2 m and 4 m chimneys, which were processed using the AERMOD View software, can be seen in Figure 4 and Figure 5.

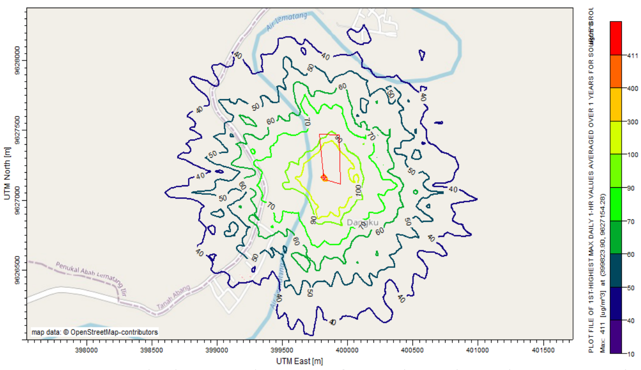

Figure 4. Isopleth contribution of NO2 based on the 2 m stack

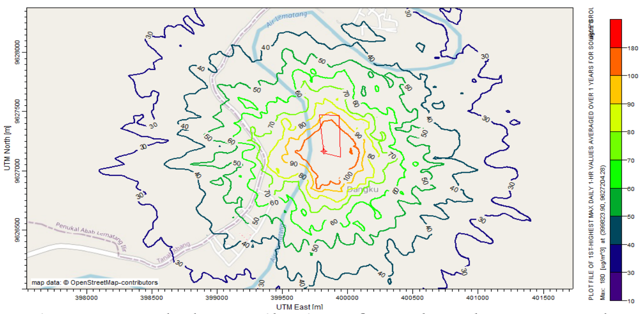

Figure 5. Isopleth contribution of NO2 based on 4 m stack

The results of isopleth distribution modelling of the CO pollutant contribution using 2 m and 4 m chimneys, which were processed using the AERMOD View software, can be seen in Figure 6 and Figure 7.

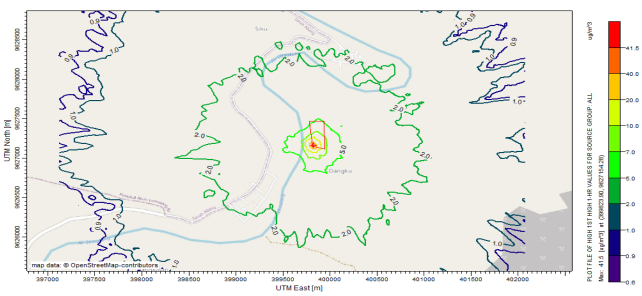

Figure 6. Isopleth CO contribution based on 2 m stack

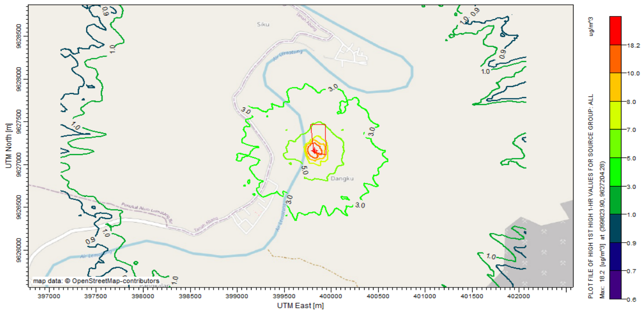

Figure 7. Isopleth CO contribution based on 4 m stack

Based on the results of AERMOD modelling, the isopleth contribution of NO2 from a 2-meter chimney will reach 411 micrograms per cubic metre, which exceeds the established air quality standard of 200 micrograms per cubic metre. The renovation was performed using a 4-meter chimney, and the isopleth contribution of NO2 decreased to 180 micrograms per cubic metre, which was below the air quality standard.

The results for the CO parameter indicate that the maximum contribution reaches 41,5 ug/m3, which is still well below the 1,000 ug/m3 air quality standard. This indicates that the isopleth contribution of CO is below the government-established air quality standard for the year 2021, based on Appendix VII of Government Regulation No. 22.

Windrose

The modeling results get the windrose pattern shown in Figure 8.

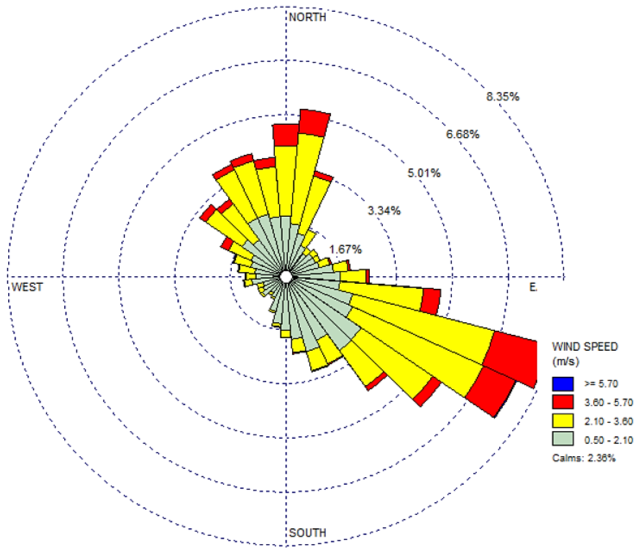

Figure 8. Windrose

The results of the wind analysis indicate that the predominant wind blows from the southeast at a rate of 8.30%. The most prevalent wind velocity occurs between 3.60 and 5.70 knots (6.63%). The predominant wind direction is southeast, which is where oil palm plantations are located, and the minimum wind direction is southwest, which is where Dangku Village, Empat Petulai Dangku District, is located.

Health Risk Level Analysis (Risk Quotient)

The results of the RQ calculation can be seen in Table 2 below:

Table 2. Risk quotient value (RQ)

No.	Parameter	Risk Level (RQ)	
		With a 2m chimney	With a 4m chimney
1.	NO_2	3,55 E-1	3,71 E-1
2.	CO	5,71 E-4	5,76 E-4

The health risk quotient of the modelling results is expressed in numbers without units which is a calculation of the comparison between intake and the reference dose, or concentration of a non-carcinogenic risk agent and can also be interpreted as safe or unsafe for a risk agent for organisms, systems, or sub-populations. The risk level analysis of a solar generator with a 2 m chimney and a 4 m chimney has an RQ value of 1 based on the calculation of the risk magnitude value (RQ). This demonstrates that neither a 2-meter nor a 4-meter chimney poses a health risk to the residents of Dangku Village, Empat Petulai Dangku District, where a specific coal terminal is located.

CONCLUSIONS AND SUGGESTIONS

Based on the results of data analysis in the study, it can be concluded that: 1) The results of AERMOD modelling recommend that the 2 m chimney on the diesel generator be modified into a 4 m chimney so that the effects of pollutant concentrations of NO2 and CO are below the air quality standards, referring to Appendix VII, PP. 22, the year 2021; and 2) The results of the risk level analysis based on RQ value one show that there is no health risk for the local community with the existence of a particular coal mining terminal using either a 2 m chimney or a modified 4 m chimney.

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