



Modelling of Air Pollution Dispersion in the Utilization of Used Oil as a Fuel

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ABSTRACT

The need for quicklime has led to increased utilization of used oil as a substitute for fuel in its combustion process. Mahaka Lime Factory produces SO₂ and NO_x, which are emitted through the chimney and proportional to lime burning. Therefore, it is necessary to monitor the distribution of the emission concentration in the ambient air. One of the methods used to facilitate the monitoring process to ensure it is kept below the quality standard is dispersion modeling. This is an analytical model processed with the help of AERMOD software and the Gaussian equation. The SO₂ concentrations of 0.001 mg/m³ and 0.001 mg/m³, as well as NO_x of 0.027 mg/m³ and 0.044 mg/m³ obtained from the calculation, were below the applicable quality standard. Furthermore, emission concentrations directly observed were more significant than the Gaussian modeling results due to the presence of other pollutants around the factory. In conclusion, the dispersion modeling using AERMOD software showed that the largest and lowest distribution of emission concentrations are in the cliff area around the emission source and on the ground surface close to the chimney.

Keywords : AERMOD, dispersion modelling, quicklime burning, used oil

1. INTRODUCTION

The need for limestone is increasing along with the rapid development of the industry [1]. Limestone is processed into quicklime to be used as a neutralizer for acidic compounds [2]. Oktafiansyah et al. (2020) considered this material more practical, inexpensive, and safe [3]. In addition, many lime factories in Indonesia utilize waste as a fuel source during the production, such as the Limestone Factory in Rembang, which employ used oil [4]

Fresh oil used for engine maintenance will become waste after some time [5]. Hidayat & Basyirun (2020)

stated that used oil sourced from industry is relatively cleaner and easier to purify with simple treatments such as filtering and heating [6]. This oil type is composed of long-chain organic components of hydrocarbons which allow it to produce valuable liquid products [7]. The combustion process to break down the hydrocarbon chains into simpler compounds is called pyrolysis [8].

One of the sources of pollutants in industrial areas is factory's chimneys, and the concentration produced affects the surrounding environment [9]. Factory is always associated with the pollution because of the very visible activities in releasing various chemical compounds into the surrounding environment [10].

Lime burning produces harmful pollutants such as CO_x, NO_x, SO_x, and other heavy metals [11]. At high temperatures of 800 to 1,000°C, it produces gas and dust trapped in the filter [12].

Mahaka Lime Factory, located within the territory of PT Freeport Indonesia (PTFI), produces quicklime, which is used to process mineral ore. This factory also mixes used oil from operational waste and machine maintenance at the ore processing plant with diesel for fuel. Furthermore, from the lime burnt in Mahaka, ambient air produced every semester comprising SO₂ gas with a value of less than 2 mg/m³ at the end of 2019 [13].

Pollutant emissions and atmospheric concentrations can be linked using air quality modeling, such as the dispersion model [14]. Patmasari (2018) defined dispersion as the continuous pollutant flow released from an immovable source, such as a chimney, which is blown by the wind, spreading its concentrations [15]. The mathematical model used to predict pollutant concentrations from various sources is the application of various atmospheric conditions [16]. Therefore, to determine the spread of pollutant dispersions, a software is needed to map the spread, such as AERMOD [17].

2. PROBLEM STATEMENT

Lime is one of the mixed ingredients used by PTFI in processing mineral concentrates. Besides the processing, it also produces hazardous and toxic (B3) waste in the form of used oil, which is utilized as a substitute for fuel in lime burning. Apart from saving fuel, this process is also used to reduce the B3 waste produced. In Mahaka, the pollutants produced are comparable to the lime burning performed, hence, they need to be monitored periodically to ensure the concentrations remain below the quality standard. However, dispersion modeling is needed to facilitate the monitoring process. Based on this explanation, the problem formulation is strategies needed to determine the distribution of emissions from lime burning in the factory.

3. RESEARCH OBJECTIVE

This research aims to determine the distribution of SO₂ and NO_x emissions due to lime burning in Mahaka Lime Factory. Visualization of the emission distribution was carried out with the help of AERMOD software to easily monitor the resulting emissions and ensure it remains below the quality standard.

4. THEORETICAL REVIEW

Used oil is a waste obtained from lubrication, mineral, or synthetic oil [18]. According to Alvarracin et al. (2021), proper management is essential for its use as fuel to avoid negative impacts on human health and the environment [19]. In addition, burning produces gas emissions in the ambient air, which need to be managed by conducting an inventory process, such as identifying sources and types of emissions, as well as calculating ambient air quality [20].

Air dispersion modeling estimates the amount of emission reduction from the source to the ground level. Anggarini et al. (2020) stated that emissions from burning activities in mining areas are a global environmental problem [21]. Dispersion modeling, which includes pollutant concentrations, chemical reactions, building effects, meteorology, plume rise, and pollutant deposition, is accomplished by simulating using an application such as AERMOD [22].

AERMOD is a spatial distribution model recommended by USEPA to predict the spread of air quality from up to 10 different sources [23]. The advantage is that it can predict the ground-level concentration (GLC) due to the effect of the planetary boundary layer (PBL) [24].

5. METHODS

This research was conducted in Mahaka Lime Factory in Mimika, Papua, Indonesia, using an analytical modeling method with the help of AERMODView version 8.9.0 software. The data used were SO₂ and NO_x emissions, chimney height, diameter, coordinates, ambient air temperature, and wind speed each semester in 2019. These parameters were the most pollutant in ambient air and affect human respiration [25]. The data processing stage is as follows figure 1.

6. RESULT AND DISCUSSION

PTFI is a copper and gold mining industry operating in the 53S zone according to the Universal Transverse Mercator (UTM) of Mimika Regency, Central Papua. One of the factories within the territory is Mahaka Lime, which uses mineral concentrates manufactured by PTFI to produce lime as a mixture. Mahaka, which has one chimney with a height and diameter of 29.6 m and 2.1 m, is located at an altitude of 3,625 m above sea level with a constant surface wind speed of 1.94 m/s [26].

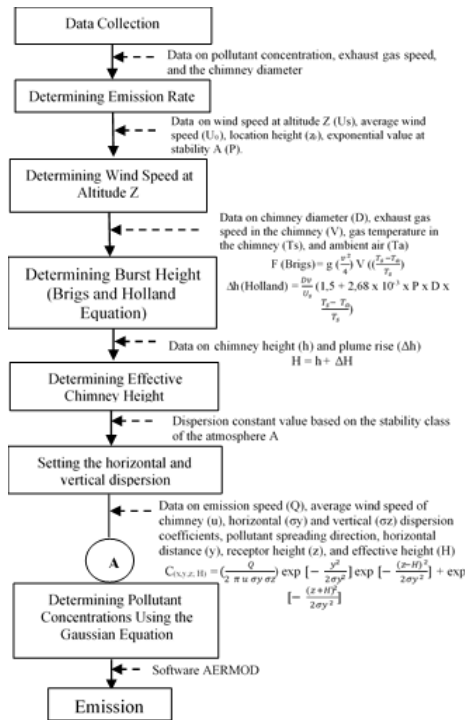


Figure 1. Flowchart of Data Processing Stage

	Latitude	Longitude	Unit
Reference Point (SW)	4° 4'24.37"S	137° 7'8.14"E	degree
	735.245	9.549.446	meter
Chimney Coordinate	4° 4'13.70"S	137° 7'20.45"E	degree
	735.626,06	9.549.773	meter

Table 1. Coordinate Points of Mahaka Lime Factory
Source: (Google Earth, 2022)

PTFI utilizes limestone in the Grasberg mining area for mineral concentrate processing, and the lime produced is used to neutralize acidic waters in mineral rocks. According to Susanto (2020), Mahaka has a maximum production capacity of 400 tons of lime per day. In its production activities, lime burning utilizes used oil as one of its fuels and produces gas in the chimney with an average temperature of 130°C. Besides, the factory still utilizes used oil and diesel at a ratio of no more than 80% [27].

Used oil comes from workshop and machine maintenance activities in the Concentrating Division. It is also produced by removing a mixture of oil and water

in the Oil Water Separator (OWS). Before being utilized again, used oil is first separated from water using OWS at Likupang Yard. This tool works in accordance with Stokes' Law, stating that the floating speed of a particle is based on its specific gravity and size using the gravitational system [28].

The used oil obtained from use and workshop activities is pumped to Mahaka to be utilized as fuel. In lime burning, different ambient emissions are produced with varying concentrations. The resulting emissions are measured and tested against the applicable quality standards based on the Government Regulation No. 22 of 2021.

Table 2. Parameters of Quality Standards and Emissions from Direct Observation at 10% Oxygen

Source: (PP, 2021; PTFI, oxygen, temperature

2019 (test result at 10% 25°C, and 1 atm)).

Parameter		Unit	Standard	Test Results	
				Semester 1	Semester 2
Sulfur (SO ₂)	Dioksida	mg/m ³	0,15	1,99	1,48
Nitrogen (NO _x)	Dioksida	mg/m ³	0,2	54	110,6

The direct observations results in Table 2 showed that emissions from lime burning utilizing used oil do not meet the applicable quality standards. Therefore, the emission distribution is further visualized using

mathematical modeling by employing SO₂ and NO_x for 2 semesters. The exhaust gas speeds were 43.32 m³/s and 33.82 m³/s in the first and second semesters, respectively

Table 3. Emission Concentration SO₂ and NO_x

Remarks	Unit	SO ₂		NO _x	
		Semester 1	Semester 2	Semester 1	Semester 2
Observed emission concentration	mg/m ³	1,99	1,48	54,00	110,60
Emission load	g/s	0,09	0,05	2,34	3,74
Wind speed (Z=0)	m/s	0,29	0,29	0,29	0,29
Burst height	m	5.718,88	2.721,24	5.718,88	2.721,24
Plumee rise height (Briggs)	m	1.559,98	1.159,05	1.559,98	1.159,05
Plumee rise height (Holland)	m	450,28	351,53	450,28	351,53
Effective height	m	479,88	381,13	479,88	381,13
Concentration (Gaussian)	mg/s	0,032	0,019	0,874	1,397
Concentration (Gaussian)	mg/m ³	0,001	0,001	0,027	0,044

Table 3 shows a comparison of emission concentrations from direct observations calculated using Gaussian. The calculated emission values showed that SO₂ and NO_x concentrations are below the quality standard, thereby considering safe for discharge into the ambient air. However, emissions of SO₂ as well as NO_x in semesters 1 and 2 are higher than concentrations calculated using Gaussian.

The comparison between the direct observation, which is more significant than the modeling, supports the research by Sari (2017). This is due to the presence

of other pollutant sources in the environment around the factory, which increases the emission concentration during direct measurements. Meanwhile, the calculation using the Gaussian model is smaller because the emission concentration is considered pure without any other pollutant sources. It is also affected by the wind direction as well as the determination of vertical and horizontal distances [29].

The data in Tables 1, 2, and 3 are entered into the AERMOD software for mathematical modeling, in the form of the NO_x distribution produced in semesters 1 and 2 of 2019 in the area around Mahaka. Figure 2 is

the distribution map obtained after all the data have been successfully run

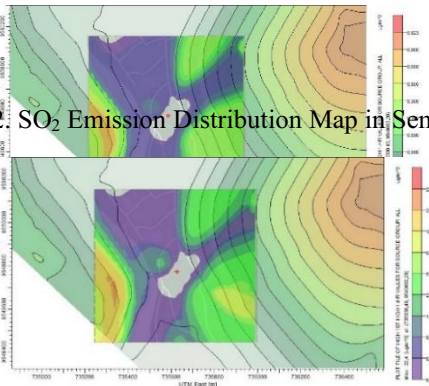


Figure 2. SO₂ Emission Distribution Map in Semester 1.

Figure 3. NO_x Emission Distribution Map in Semester 1.

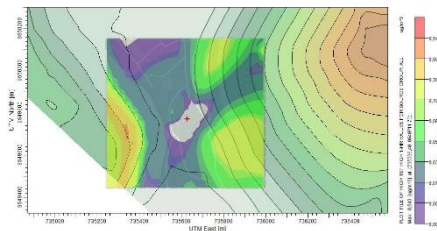


Figure 4. SO₂ Emission Distribution Map in Semester 2.

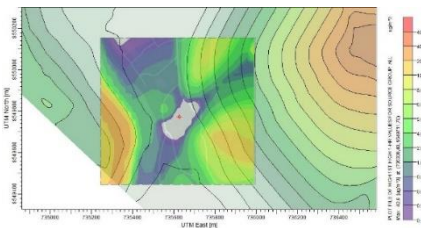


Figure 5. NO_x Emission Distribution Map in Semester 2.

Figures 1, 2, 3, and 4 represent the differences in SO₂ and NO_x concentration values, which affect the distribution of these emissions in ambient air. The red dot in the center is Mahaka chimneys, which are considered a stationary emission source. The minimum and maximum values of SO₂ and NO_x concentration on both maps are in the ground surface and cliff areas around the factory chimneys. Wind speed also affects this distribution, where the greater it is, the lower the concentration (Sarwono et al., 2022). The wind speed

near the chimneys tends to be faster than in the cliff area because it is blocked by the walls.

Based on the emission distribution map above, the wind tends to blow from east to west, as seen from the red color on the map, most of which are in the western part. The red color indicates the area with the largest concentration of emissions. Meanwhile, when the color turns to purple, it means that the area has the lowest emission concentration. Wind that tends to be strong is also caused by high levels of humidity and air pressure.

CONCLUSION AND SUGGESTIONS

Utilization of used oil as a fuel substitute in burning quicklime in Mahaka Lime Factory produces SO₂ and NO_x emissions. It was reported that these concentrations were above and under the applicable quality standards based on direct observation and the Gaussian model, respectively. The data further showed a distribution map of SO₂ and NO_x around the factory area using AERMOD software. The map showed that the highest and lowest emission concentrations were in the cliff area and ground level around the chimneys, respectively. The low concentration was caused by the wind speed, which plays a role in the distribution of air dispersion. Unfortunately, this research has limited detailed data on wind direction as well as wind speed per day, thereby making it impossible to visualize wind direction using Windrose.

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