International Journal of Society Reviews (INJOSER) e-ISSN: 3030-802X
Vol. 2 No. 1, January 2024, pages: 13~24

ANALYSIS OF THE DISTRIBUTION OF AIR POLLUTANTS USING THE AERMET METEOROLOGICAL MODEL AND THE GAUSSIAN DISPERSION MODEL

Amran *[1]
Mining Engineering Study Program, Faculty of Engineering, Bosowa University
amran@universitasbosowa.ac.id

Wahyuni
Universitas Pejuang Republik Indonesia
wahyuni.chem@gmail.com

Alwi Sibali
Polimarin AMI Makassar
Captalwisibali@gmail.com

Enni Tri Mahyuni
Department of Mining Engineering, Faculty of Engineering, UPRI
enni.tri@universitasbosowa.ac.id

Firman Menne
Accounting Study Program, Faculty of Economy, Bosowa University
firman@universitasbosowa.ac.id

Malik
Universitas Cokroaminoto Makassar
0904087301malik@gmail.com

Mohamad Ali Wardana
Universitas Lamappapoleonro Soppeng
aliwardana99@gmail.com

Abstract

Air pollution is a condition where air quality decreases and is contaminated with substances, and if these substances are dangerous or not dangerous, they can cause human health problems. One type of pollutant that needs to be considered is air pollution due to the operation of machines. Machine operation using Palm Shells, and diesel fuel for factory operations. As a result, the operation of the engine produces several exhaust gases such as Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Particulates (PM), and Mercury (Hg). To find out the distribution pattern of chimneys, you can use the Aermod View software, and data processing is needed on Aermap. In this study, the meteorological data analysis method was used with the data input system in the Aermod View software. The purpose of this study is the analysis of meteorological data for Aermod View software input. The data obtained is meteorological data

[1] Correspondence author

consisting of wind direction, wind speed, reference wind height, temperature, rainfall, air humidity, surface pressure, and cloud cover. Emission dispersion model for stacks on SO_2, NO_2, CO, and particulate parameters. The location that has the potential to receive high concentrations of these pollutants is east to southeast from the source due to a higher elevation of up to 96 meters. The maximum concentration of SO_2, NO_2, C, O, and particulates is at a distance of 800 meters from the emission source to the east. The condition of the area that has the maximum concentration is dominated by agricultural areas. From the results of modeling without a controller, the maximum SO_2 concentration at the receptor is 50.2 µg/m^3 while the quality standard is 150/1H, the maximum NO_2 concentration at the receptor is 128 µg/m^3, the quality standard is 200/1H, the concentration of Carbon Monoxide (CO) is 5338 µg/m^3, standard quality standard 10000/1H, The modeling results show that without using controllers, pollutant concentrations are still within the quality standards that have been set based on PP No. 22 of 2021.
Keywords: AERMOD, Emissions, Modeling, Air Dispersion, Auxiliary boiler

Introduction

Atmospheric dispersion modeling was carried out to predict the magnitude of the impact of boiler emissions on the surrounding air quality to assess the cumulative impact of operational emissions. Estimation of pollutant distribution is carried out by modeling using AERMOD Version 9.8 software taking into account several emission factors from contaminants, chimney height, local topography, and meteorology. The main meteorological aspects considered in this modeling are wind speed and wind direction, temperature, mixing height, and atmospheric stability. The purpose of this modeling is to determine the contribution of SO_2, NO_2, CO, and particulate emissions to the environment.

Basic Theory

Air can be interpreted as an important factor in supporting life and has become a global concern because its quality is decreasing over time (Baturante and Kumendong, 2022), and air pollution has become a major problem in recent years (Salva et al., 2021).

The problem of air pollution has also been thought of by humans for a long time, the main problem is local emissions which have a negative impact on air quality (Idris et al., 2020). The ambient air distribution needs to be modeled. This is also related to the health of the community around industrial areas (Ofrial et al., 2020).

The rapid industrial development areas in Indonesia provide two contradictory conditions. Namely providing economic benefits, and on the other hand causing an increase in the concentration of pollution due to industrial waste itself. If the increase in the industry is not followed by good environmental management, it will have a negative impact on environmental quality (Subardjo et al, 2016).

Air is the most important substance after water in providing life on this earth's surface. In addition to providing oxygen for breathing purposes, air can also be a medium for the spread of disease in humans. In a situation when the pollution that occurs exceeds the ability of nature to clean itself, the pollution will endanger human health, and have a broad impact on the existing ecosystems in the environment. The gases and odors emitted from the landfill have negative impacts on the environment and health (Sonibare, Adeniran, & Bello, 2019).

Air is an important component of the life of all living things. Ambient air is free air on the earth's surface in the troposphere which is within the jurisdiction of the Republic of Indonesia which is needed and greatly affects the health of humans and living things, and other environmental elements. A condition where air quality decreases and is contaminated with substances, and if the substance is harmful or harmless it causes health problems in humans, it is called air pollution. Air pollution can come from natural and human activities. Natural activities such as volcanic eruptions and forest fires. Meanwhile, sources of air pollution come from human activities such as industry and transportation (Lunaria, 2017).

The American Meteorology Society Environmental Protection Agency Regulatory (AERMOD) is software based on the Gaussian plume model recommended by the United States Environmental Protection Agency (US EPA) for air quality simulation (EPA, 2005; Rood, 2014 in Natsir et al., 2018).

AERMET is a meteorological model that calculates hourly wind and temperature parameters on a three-dimensional grid. Related two-dimensional parameters such as mixing height, surface characteristics, and dispersion properties are also displayed by AERMET. AERMET product is a meteorological file used by AERMOD to predict the movement of air pollutants.

AERMOD is a non-steady three-dimensional Gaussian puff model developed by the US Environmental Protection Agency (US.EPA) for use in conditions where the basic Gaussian model is ineffective. This condition includes stagnant conditions, which are characterized by conditions with no wind or very low wind speeds with changing directions. The AERMOD modeling system can model wind changes and spatial turbulence.

The Gaussian dispersion model can describe simply the state of particles in air concerning distance and time. Emissions that are generated constantly from the chimney (Q) will be carried by the wind at a speed (u) in the horizontal direction (x) with a mass velocity Q/u. For unreacted pollutants, the mass of the pollutant contained at any distance will be the same value. However, the levels will decrease with increasing distance and time, because atmospheric turbulence tends to spread the material in horizontal and vertical directions. The average pollutant level at a point will be inversely proportional to the distribution width and wind speed. The Gaussian model is expressed in Eq below.

$$C = \frac{Q}{2\pi u_s \sigma_y \sigma_z} exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y{}^2}\right) \times \left\{exp\left(-\frac{1}{2}\ x\ (z - He)^2\right) + exp\left(-\frac{1}{2}\ (z + He)^2\right)\right\}$$

Where:

C = Concentration of air pollutant in mass per volume (mg/m³)
Q = Pollutant emission rate in mass per time (mg/s)
U_s = Wind speed at source point (m/s)
σ_x = horizontal dispersion coefficient (m)
σ_y = Coefficient of vertical dispersion (m)
π = Mathematical constant (3,14)
He = Effective height of the stack (chimney) at the center of the puff (m)
Y = Observation distance parallel to the y-axis from the emission source (m)

Method

Dispersion Models

AERMET meteorological processor and AERMOD dispersion model (BC Ministry Of Environment, 2015) are used as modeling applications.

Table 1. Model Input Parameters

PARAMETERS	INPUT
AERMET	
Grid Center Reference Coordinates	1°38'57.46"S, 119°17'36.48"E
Simulation Time	10 Years (2013-2022)
Surface Meteorological Station	NASA Prediction Of Worldwide Energy Resources
Upper Air Meteorological Station	NOAA/ESRL Radiosonde Database
Topographic Data	Altitude taken from SRTM3, resolution 90 meters
AERMOD	
Modeling Domains	Computing Grid: 1.5 km x 1.5 km
Grid Resolution for Mapping Modeling	Grid Resolution: 502,3 meter
Number of Modeling Hours	87.640 Hours
Meteorological Modeling Period	January 1st 2013 – December 31st 2022

Model Input Determination

In this study, there is 1 source point, namely the boiler chimney with a capacity of 4 tons/hour. The chimney parameters used as modeling data input are presented in Table 2. Emission rates are determined based on emission rate calculations using emission factors from the European Environment Agency which have been outlined in the Technical Guidelines for Making an Inventory for Urban Air Pollutant Emissions (KLHK).

Table 2. Emission Source Parameters

No.	DATA TYPE	BOILER
1	Fuel Type	Shells and Palm Fibers
2	Chimney Height (m)	20
3	Diameter of Chimney (m)	0,75
4	Gas Temperature (°C)	350 (Max)
5	Exhaust Gas Velocity (m/s)	24
6	Gas Emissions Debit (m^3/s)	10,60
9	Consumption (Ton/Jam)	4
10	HHV Energy (Kkal/kg)	3457.42
11	Chimney Coordinates (GC Lat/Long) WGS84	1°38'57.46"S, 119°17'36.48"E
12	Elevation (m)	19

From the amount of fuel consumption, it can be analyzed the value of emissions that can be produced by the chimney. Based on the emission factor data of Combustion in the manufacturing industry by EEA.

Table 3. Emission Rate based on Emission Factor

No.	PARAMETERS	EMISSION FACTOR (g/GJ)	ENERGY (Kcal/kg)	EMISSION RATE (g/s)	
				No Controller	With Controller
1	NO_x	33,4	3457.42	2.7567	0.6892
2	SO_2	8,5	3457.42	0.7057	0.1764
3	CO	0,25	3457.42	29.3315	7.3329
4	PM	6,5A	3457.42	2.6281	0.6570

Source: Technical Guidelines for Preparation Inventory of Air Pollutant Emissions in Urban Areas (KLHK) and Results of Emission Rate Analysis, 2023

Meteorological Conditions

Wind Rose is a frequency distribution of wind direction and other parameters that provide a quick view of wind speed and distribution of paths at a specified location on a certain date and period (Aly, 2018). Wind rose is the result of data from wind direction and wind speed which is used to see the dispersion and distribution of the dominant wind direction that carries emission particles. The scale used uses the Beaufort Scale (Ismahami and Anurogo, 2022).

Meteorological conditions determine the direction of emission movement and the distribution of emissions carried by the wind. Key meteorological parameters include air temperature, direction and speed of wind, and mixing height. For modeling purposes, hourly data is required in the modeling period for each key parameter. For this reason, the NCAR (National Center for Atmospheric Research) MM5 (Mesoscale Model) prognostic data was used, obtained from the NASA POWER meteorological database, for the period January 1st, 2013 to December 31st, 2022 (10 years). This data is then processed by AERMET, which is a meteorological data processor for AERMOD. Windrose or wind rose is a depiction of wind direction and dominant wind speed in a place at a certain time. After processing the wind speed and wind direction data in the WRPLOT software, the windrose results obtained will be compared with the isopleth modeling results in the AERMOD software. In the windrose diagram, wind speed is classified into several colors based on the level of wind speed, namely light green for the speed range of 0.5 – 2.1 m/s, yellow for the speed range of 2.1 – 3.6 m/s, red for the speed range speed 3.6 – 5.7 m/s, blue for speed range 5.7 – 8.8 m/s, dark green for speed range 8.8 – 11 m/s, and light blue >= 11 m/s. The average 10-year Windrose can be seen in Figure 1.

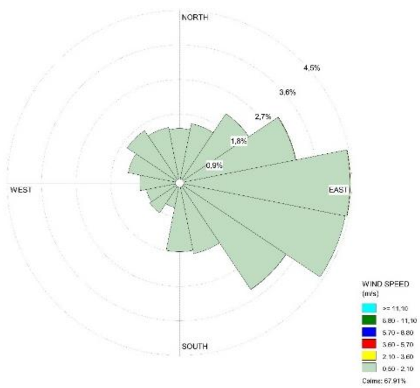

Figure 1. Windrose

The wind distribution pattern for each year, from 2013 to 2022 (10 years) shows no very big changes. In addition, there are also no major differences in the pattern of distribution each year. The pattern, direction, and speed of the wind must be considered because they are the most influential factors in modeling the distribution of chimney emissions.

Table 4. Wind distribution data (2013-2022)

No.	MONTH	TOTAL DATA (Hours)	CALM WIND (%)	SPEED AVERAGE (m/s)	DOMINANT DIRECTION (Degrees)
1	January	7433	67.93	0.34	123.75 – 146.25
2	February	6769	67.65	0.34	123.75 – 146.25
3	March	7441	67.40	0.31	123.75 – 146.25
4	April	7201	65.82	0.32	123.75 – 146.25
5	May	7441	69.17	0.31	78.75 – 101.25
6	June	72.01	69.81	0.32	101.25 – 123.75

No.	MONTH	TOTAL DATA (Hours)	CALM WIND (%)	SPEED AVERAGE (m/s)	DOMINANT DIRECTION (Degrees)
7	July	7441	69.33	0.34	78.75 – 101.25
8	August	7441	70.56	0.36	78.75 – 101.25
9	September	7201	66.74	0.40	78.75 – 101.25
10	October	7441	66.74	0.37	78.75 – 101.25
11	November	7201	68.10	0.33	78.75 – 101.25
12	December	7441	65.51	0.36	123.75 – 146.25
13	2013-2022	87640	67.91	0.34	78.75 – 101.25

Source: WRPLOT Analysis Results, 2023

Modeling Regions and Representative Receptor Networks

For this study, the emission distribution was modeled in a 1.5 km x 1.5 km area with a chimney as the center. For AERMOD Input, the receptor points are modeled in the form of a representative receptor network (grid). The pollutant concentration distribution is calculated based on this receptor network. In this model, the receptor network is modeled as a cartesian network with a Chimney as the center point, and the receptor points are placed in a grid = 441 representative receptor points.

Topography

Topography affects the distribution of pollutant concentrations at certain points. For this reason, topographic data is needed to input the AERMOD model, in this study, topographic data is taken from SRTM3 90m (webgis).

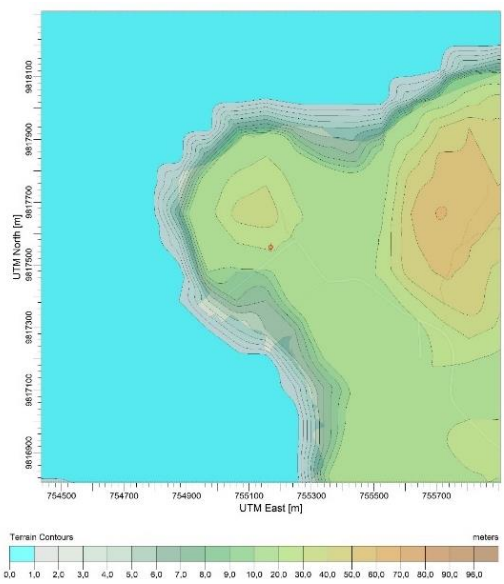

Figure 2. Contour Map of Study Area

Quality standards

The ambient air SO_2, NO_2, CO, and PM concentrations predicted by AERMOD View were compared with ambient air quality standards. These assessment criteria are intended to minimize the negative impact of air pollutants on sensitive receptors. The ambient air quality standard refers to Government Regulation No. 22 of 2021. Meanwhile, Boiler Emission Quality Standards are based on Minister of Environment Regulation No. 07 of 2007 concerning Stationary Source Emission Quality Standards for Steam Boilers.

Table 5. Quality Standards

NO	PARAMETERS	EMISSION QUALITY STANDARD (mg/m³) *	AMBIENT AIR QUALITY STANDARD (µg/m³) **
1	Nitrogen Oxide (NO_2)	800	200/1H
2	Sulfur Dioxide (SO_2)	600	150/1H
3	Carbon Monoxide (CO)	-	10000/1H
4	Particulate (PM_{10})	300	75/24H

*PermenLH 07 of 2007
**PP No. 22 of 2021

Modeling Results and Discussion

The scenario for modeling pollutant dispersion is in the form of isopleth emission concentrations above ground level from a relatively constant pollutant load but with different pile configurations. Annual average meteorological conditions greatly influence the pattern of emission dispersion in the distribution model,
In addition, the configuration of buildings including new buildings in the test area is also considered. Based on the results of the analysis, the concentration of emissions dispersed by a boiler with a capacity of 4 tons/hour of palm shells is as follows.

Table 6. Emission Load on Boilers

Fuel	NO_2	CO	SO_2	PM_{10}	Unit
Palm Shell Emission Factors	150	1596	38.4	143	g/GJ
Emission Rate	2.7567	29.3315	0.7057	2.6281	g/s
Emission	**260.00**	**2766.36**	**66.56**	**247.86**	**mg/m³**
Quality Standards*	**800**	**-**	**600**	**300**	**mg/m³**

**PermenLH 07 of 2007*

Chimney Emission Distribution Model

The emission dispersion model for the chimney is shown in Figure 2 to Figure 9., for SO_2, NO_2, CO, and Particulates respectively. Locations that have the potential to receive high concentrations of these pollutants are in an east-to-southeast direction from the source, due to a higher elevation of up to 96 meters.

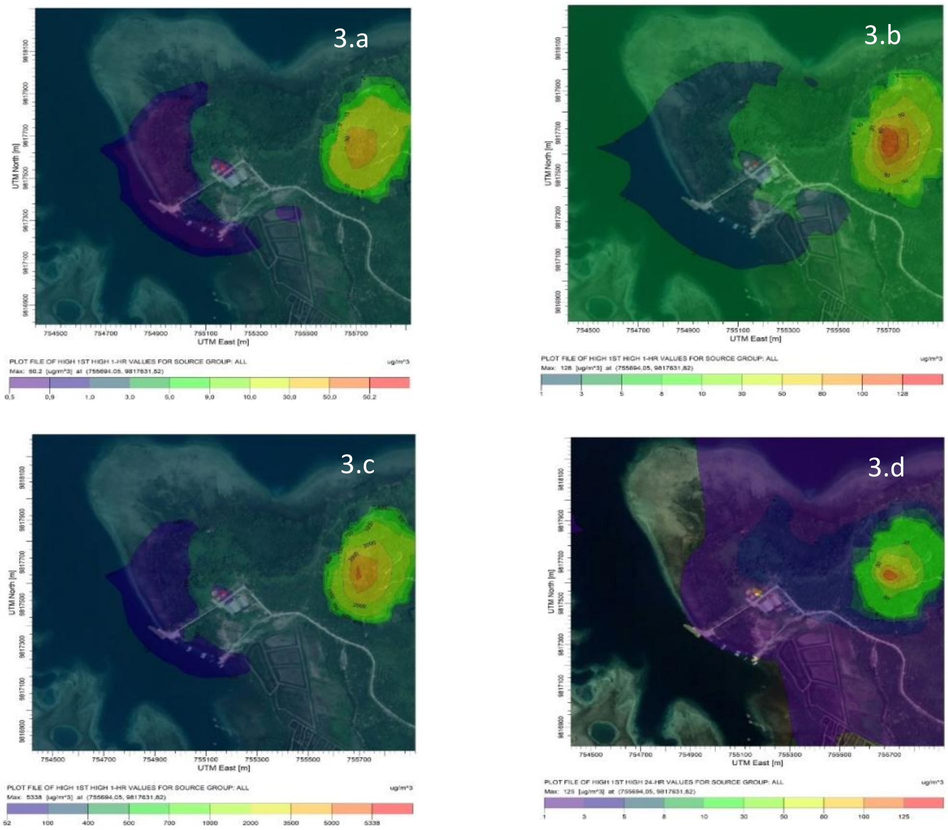

Figure 3. Isopleth distribution without control for (a). Isopleth Distribution of NO_2, (b). Isopleth Distribution of SO_2, (c). Isopleth Distribution of CO, (d). Isopleth PM Distribution.

The maximum concentration of SO_2, NO_2, CO, and particulates is at a distance of 800 meters from the emission source to the east. The condition of the area that has the maximum concentration is dominated by agricultural areas. A summary of the maximum concentrations can be seen in Table 7 and Table 8.

Table 7. Maximum Concentration of AERMOD Modeling Results (Without Controller)

No	Parameters	Maximum Concentration ($\mu g/M^3$)	Quality Standards*
1	Nitrogen Oxide (NO_2)	128	200/1H
2	Sulfur Dioxide (SO_2)	50.2	150/1H
3	Karbon Monoxide (CO)	5338	10000/1H
4	Particulate (PM_{10})	125	75/24H

*PP No. 22 of 2021,

The comparison to the operational plan is by adding control equipment to the boiler chimney in the form of a cyclone with an efficiency of 75%. Based on the efficiency, the pollutant concentration in the dispersion model produced in ambient air decreases. The distribution pattern with control equipment is detailed in the following figure.

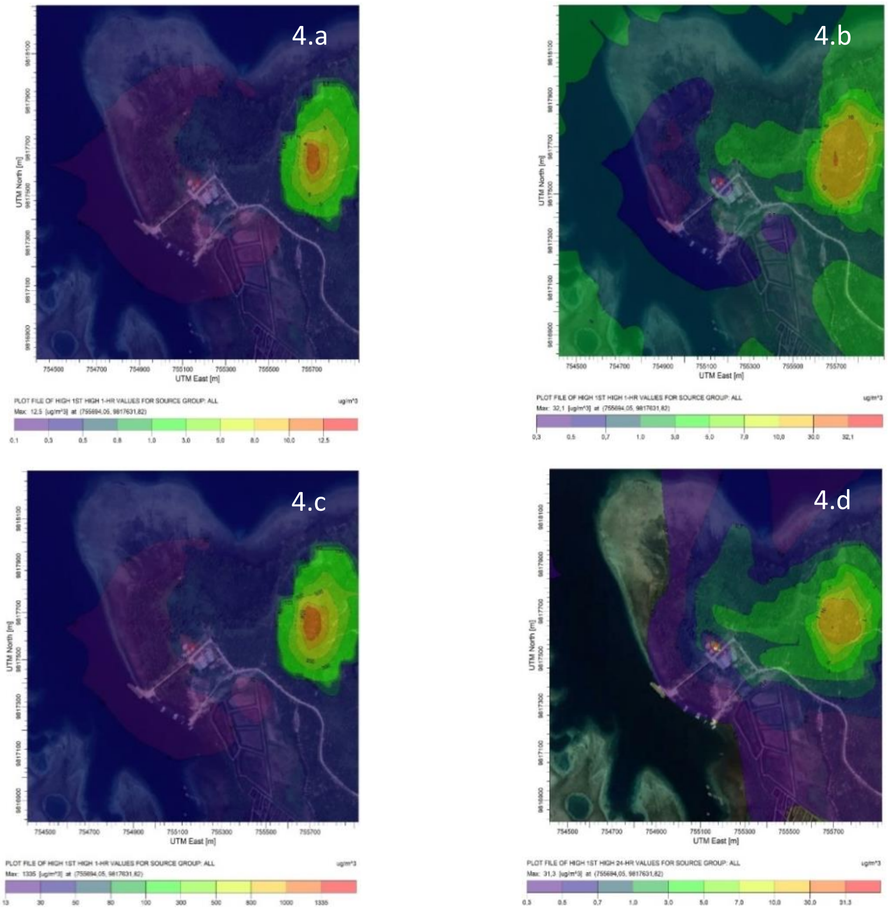

Figure 4. Distribution Isopleth with Controller (a). Isopleth Distribution of NO_2, (b). Isopleth Distribution of SO_2, (c). Isopleth Distribution of CO, (d). Isopleth PM Distribution.

Table 8. Maximum Concentration of AERMOD Modeling Results (With Controller)

NO	PARAMETERS	MAXIMUM CONCENTATION (µg/m³)	QUALITY STANDARD*
1	Nitrogen Oxide (NO_2)	32.1	200/1H
2	Sulfur Dioxide (SO_2)	12.5	150/1H
3	Karbon Monoxide (CO)	1335	10000/1H
4	Particulate (PM_{10})	31.3	75/24H

*PP No. 22 of 2021

Conclusion

The study results show that locations that have the potential to contain high concentrations of pollutants are in the east to southeast direction of the pollutant source, because of the higher elevation of up to 96 meters. The maximum concentration of **SO_2** is **50.2 μg/M^3** below the quality standard 150/1H, Nitrogen Oxide Concentration (NO_2) is **128 μg/M^3** below the quality standard 200/lH. The Carbon Monoxide (CO) is **5338 μg/M^3** below the quality standard that has been set at 10000/1H. and particulates are at a distance of 800 meters from the emission source to the east with a concentration of **125 μg/M^3**, which is within the concentration limits of the quality standards that have been set. It appears that the condition of the area that has the maximum concentration is dominated by agricultural areas, where the concentration is modeled before adding a controller in the form of a boiler chimney.

The modeling results after comparing the operational plan are by adding control equipment to the boiler chimney in the form of a cyclone with an efficiency of 75%. Based on its efficiency, the concentration of pollutants in the distribution model produced in the ambient air decreases as shown in Table 8 above.

References

Aly, S. H. dkk. 2018. *Aplikasi Model AERMOD Dalam Mempredksi Sebaran Emisi Cerobong Asap PLTD Tello, Makassa.* Jurnal Prosiding Seminar Ilmiah Nasional Sains dan Teknologi, Vol 4.

Baturante, N. J., dan Kumendong, N. (2022) "*Pengaruh Tinggi Dan Diameter Cerobong PLTU Terhadap Dispersi SO2 Di Udara Menggunakan Model Gaussian Plume*", Jurnal Pendidikan Kimia Unkhair (JPKU), 2(1), 1–8.

BC Ministry Of Environment. (2015). *British Columbia Air Quality Dispersion Modelling Guide*. Environmental Protection Division, Victoria, British Columbia, Canada.

EMEP. EEA, (2019). *Air Pollutant Emission Inventory Guidebook 2019.* Europan Environment Agency.

Ismahani, Rosita., Anurogo, Wenang. 2022. *Pemodelan AERMOD Untuk Proyeksi Pola Penyebaran Emisi Heat Recovery Steam Generator PT X dan PT Y*. Indonesian Journal of Conservation, Vol 11.

Idris, M., Darma, T. H., Koki, F. S., Suleiman, A., Ali, M. H., Yarima, S. U., dan Aliyu, A. (2020) '*An Analysis of Air Pollution at Some Industrial Areas of Kano Using The AERMOD Model*', Bayero Journal of Pure and Applied Sciences, 12(1), 117–127.

Lunaria, J.M., Kania, D. 2017. *Analsis Dispersi Polutan Dari Multiple Source Operasional PLTU Batubara X Sebagai Media Perhitungan Valuasi Ekonomi*. Jurnal Teknik Lingkungan, Vol 23.

Menteri Negara Lingkungan Hidup. (2007). *Peraturan Menteri Negara Lingkungan Hidup No. 07 Tahun 2007 Tentang Baku Mutu Emisi Sumber Tidak Bergerak Bagi Ketel Uap*.

Ofrial, S., Zakaria, A., Herianto, D., dan Wisena, F. D. (2020) '*Pemodelan Dispersi Udara Ambien Oleh Polutan Karbon Monoksida Sektor Transportasi di Kota Bandar Lampung*', Jurnal Teknologi Dan Inovasi Industri, 01(02), 16–21.

Pemerintah Republik Indonesia. (2021). *Peraturan Pemerintah No 22 Tahun 2021 Tentang Penyelenggaraan Perlindungan*.

The US. EPA, (2019). AP-42: *Compilation of Air Emissions Factors.* United States Environmental Agency.

Sonibare, O. O., Adeniran, J. A., & Bello, I. S. (2019). *Landfill air and odor emissions from an integrated waste management facility*. Journal of Environmental Health Science and Engineering, 17(1), 13–28.

Salva, J., Vanek, M., Schwarz, M., Gajtanska, M., Tonhauzer, P., dan Ďuricová, A. (2021) 'An Assessment of The On-Road Mobile Sources Contribution to Particulate Matter Air Pollution by Aermod Dispersion Model', Sustainability (Switzerland), 13(22).

Subardjo, P., Ario, Handoyo. 2016. "*Pola Persebaran Limbah Pemanasan PLTU Di Kolam Pelabuhan Tambak Lorok Semarang*". Universitas Diponegoro: Semarang.