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Prediction of coal dust dispersion to total suspended particulate (TSP) concentration in ambient air quality, case study: *PLTU* Tanjung Jati B

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Abstract. According to the National Medium-Term Development Plan set a 35000 MW target in 2019, wherein 2016, coal still dominated the power plant's fuel, which is 62%. The fastest rate of consumption is 4,7% per year since 2002; by the domination of coal-fired power plant in Indonesia in 2005 with 29.4 million tons of coal consumption, it is projected to be an increment in 2020 with 75 million tons of coal consumption. This condition could lead to generated coal dust, potentially impacting the ground concentration of TSP in the ambient air quality. The further impact may lead to environmental & social issues in the community residence of surrounding coal-fired power plants (*PLTU*). Considering the potential impact of coal dust emission from coal stockpile activities, then the prediction of coal dust dispersion generated from coal handling activities to determine the ground concentration of TSP is necessary to determine appropriate mitigating control to reduce the coal dust emission. Therefore, such a power plant will have mutual benefits with the surrounding area, especially the community. According to the model prediction result using AERMOD, it could be predicted that the emission contribution from the coal stockpiles is reached 100-200 μg/m^3.

1. Introduction

Emission of particulate matter where released may be primary particles (such as combustion) directly emitted by a single source, secondary suspensions of already settled particles, or transformed from a series of gaseous precursors of emission sources in the atmosphere [1]. Coal-fired Power Plant (*PLTU*) Tanjung Jati B (TJB), which has been operating starting from 2006, consist of 4 units of power plant with a capacity of 660 MW (net) of each, namely Unit 1&2 (TJB 12), and Unit 3&4 (TJB 34). The *PLTU* TJB complex is located adjacent to residential areas. According to the plan, in 2021, there will be additional TJB Unit 5 & 6 (TJB 56) with a capacity of 2 x 1070 MW (gross), so that the *PLTU* TJB complex will become the largest coal-fired power plant complex in Southeast Asia.

In order to meet the operational needs of *PLTU* TJB, a large supply of coal is required. Coal consumption of TJB 12 is ± 3.900.000 tonnes/year, TJB 34 is ± 3.500.000 tonnes/year, and TJB 56 is planned to require the consumption of 600.000 tonnes/year.

The emissions from the coal handling are affected by some variables: throughput, dumping height, particle size distribution (the type of coal), moisture content, wind characteristic and the general configuration of the pile and the dumping system [2]. The dust generated by the open-yard stockpile under the wind's action is the most severe pollution in the surrounding area's atmospheric environment.

Among coal dust emissions from the wind erosion process from open piles, the wind blowing movement over the pile surface accounts for 30%, 40% of the stacking activity, and 30% of the heavy on-site equipment transportation activity [1].

A previous study with a similar subject was conducted with a case study in Asia. Most of the studies studied coal stockpiles in coal mining, located far from the community residence. This study is specified for the coal stockpile located in the power plant area, usually close to community residences. Therefore, it could give a more comprehensive impact on ambient air quality and community residence impact.

This research objective is to have a comprehensive figure of the coal dust dispersion model and impact the magnitude of dust to TSP concentration in ambient air quality. Based on a study of the potential for significant impacts from coal stockpile activities, an estimate can be made of the distribution of coal dust emissions so that the magnitude of the effect of the concentration level on the TSP concentration in ambient air can be determined. Furthermore, it can determine the appropriate control measures to control and/or reduce the impact.

2. Methodology

Wind erosion of particulate matter from soils and aggregate piles has been studied previously, either empirically or using modeling. A common issue examined across most of these studies is the extent to which wind speed affects emissions of PM_{10} size particles [3].

Prediction of the potential for contamination distribution from coal stockpiling activities is carried out through several research steps, including (1) identification of dominant dust resuspension sources, (2) initial modeling of emission distribution by involving activity data such as meteorology, land use, area size, technical stack, (3) validation of emission distribution modeling results, by comparing TSP concentrations at several measurement points (upwind, identified wind direction as exposed to dust and control areas) derived from time-series data, (4) Quality status analysis ambient air, (5) emission modeling with worst-case scenario simulation to obtain an estimate of the distribution of coal dust emissions in TSP values. These steps can be described in the following flow diagram:

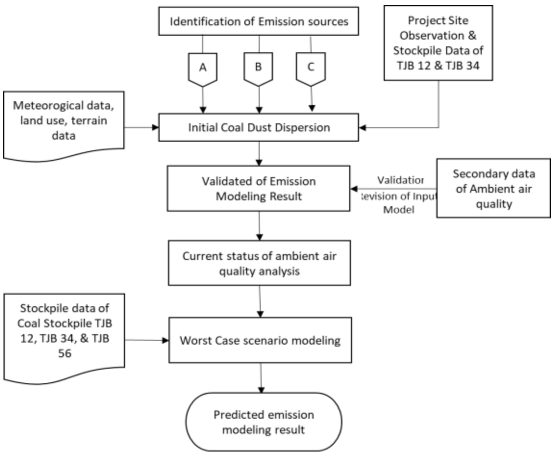


Figure 1. Flow diagram of determination coal dust emission.

2.1. Identification of emission sources

The identification of emission pollutant sources is important for control measures. In handling coal, the erosion of coal piles by the wind and the stacking-reclaimer process are estimated to be the primary sources of coal dust resuspension. Therefore, in this methodology, it is necessary to identify the dust source parameters needed in dispersion modeling. For this study, the potential source of pollutant resuspension of coal is (1) wind erosion on coal stockpile, (2) dust resuspensions from coal stacking & reclaiming process, (3) coal conveyor operation from jetty to coals stockpile.

The emission factor for each emission source is determining using the following formula:

- Wind Erosion [4].

$$EF_{TSP} = 1{,}9\left(\frac{s}{1{,}5}\right)\left(\frac{365-p}{235}\right)\left(\frac{f}{15}\right) kg/ha/day \quad (1)$$

Where:
s: silt content (%)
p: number of days when rainfall >0,25 mm
f: percentage of time that wind speed >5,4 m/s

- Stacking-Reclaiming (USEPA, AP-42, Chapter 13.2.4.)

$$EF = k \times 0{,}001 \times \left(\frac{U}{2{,}2}\right)^{1{,}3}\left(\frac{M}{2}\right)^{-1{,}4} kg/t \quad (2)$$

Where:
k: 0,74 for particle less than 30 µm
U: mean wind speed in m/s
M: material moisture content (%).

- Conveyor

Estimation of TSP emissions from conveyors is referred to AP-42, table 11.24.2, for material handling (low moisture ore <4%) (uncontrolled), as an amount of 0,12 lb/ton [5].

2.2. Analysis of ambient air quality time-series data

Analysis of time series data of ambient air quality (TSP) based on periodical monitoring results is required to have a representative figure. Determining the location for the analysis of the monitoring to be carried out is considered as follows:

Table 1. Ambient air monitoring point location.

Code	Coordinate		Description	Function
	Latitude	Longitude		
Station 1 (Source)	6°26'36.7"	110°44'10.4"	*PLTU* (source)	Source
Station 2 (QU-6)	6°28’25,8”	110°45’00,0”	Kaliaman Village	Receptor
Station 3 (QU-9)	6°27’11,8”	110°45’47,6”	Tubanan Village	Receptor
Station 4 (QU-11)	6°28’25,8”	110°45’00,0”	Bondo Village	Control

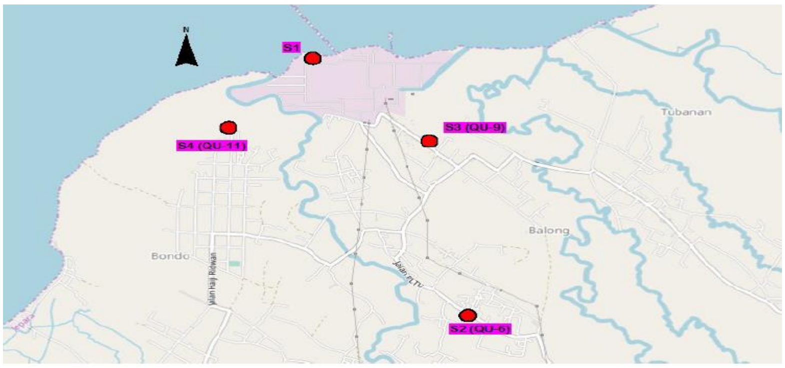


Figure 2. The layout of the monitoring point of ambient air quality.

2.3. Initial modeling of emission dispersion

Hypothetical emission distribution modeling using AERMOD software is used to estimate the distribution of pollutant concentrations from emission sources. Initial modeling will be carried out based on emission source data, project location data, meteorological data, coal stockpile technical specifications, and type of receptor area [5].

The receptor area will be divided into a 50 x 50 m grid according to the Cartesian network. The model's complete data is needed, such as meteorological data, building configuration data, emission data, and receptor data. This modeling uses the ISCST3 module developed by US-EPA.

2.4. Validation of the initial modeling result
The initial modeling results need to be validated by comparing the estimated distribution of dust concentrations with ambient air quality time-series data obtained from routine monitoring data of *PLTU* Tanjung Jati B. Time series data are measurement data for the past two years. If the modeling results show a concentration level close to the ambient air quality data, then the initial modeling parameters can be used to perform the second stage modeling.

3. Results and discussion

3.1 Identification of emission sources
This study's scope of prediction is to predict the total emission of coal dust from *PLTU* TJB 12, TJB 34, and TJB 56. Data of emission sources from TJB 12 & TJB 34 are used for the initial (1st stage) modeling. The 1st stage modeling result will be validated using secondary data of ambient air quality of dust (TSP) concentration from the periodic monitoring. Data related to emission source from *PLTU* TJB is shown in table 2.

Table 2. Data of emission source of coal stockpile.

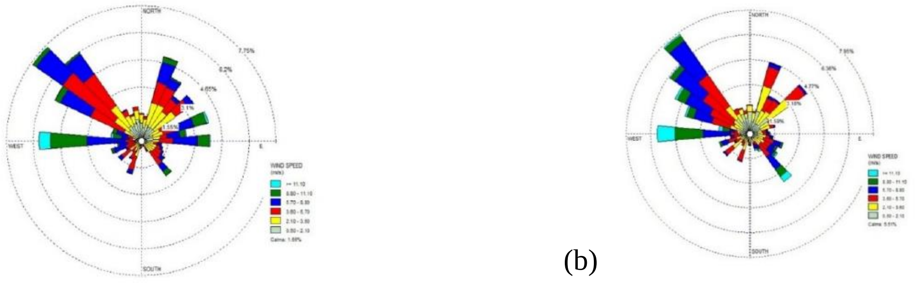
No	Type of Emission Source	Emission Source	Capacity	Remarks
1	Area source	Stockpile		
		▪ TJB 12	A= 95.000 m^2	H_{max} = 14 m
		▪ TJB 34	A = 95.000 m^2	H_{max} = 14 m
		▪ TJB 56	A = 120.000 m^2	H_{max} = 14 m
2	Point source	Stacker-reclaimer		
		▪ TJB 12	S= 1.650 ton/jam, R= 1.100 ton/jam	Operational height at H_{max}
		▪ TJB 34	S= 1.650 ton/jam, R= 1.100 ton/jam	Operational height at H_{max}
		▪ TJB 56	S= 2.500 ton/jam, R= 1.700 ton/jam	Operational height at H_{max}
3	Line source	Coal conveyor		
		▪ TJB 12	Length: 1.328,5 m Cap.: 1.500 ton/day	The above cover is installed
		▪ TJB 34	Length: 2.144,3 m Cap.: 1.500 ton/day	Above cover is installed.
		▪ TJB 56	Length: 1.280,6 m Cap.: 1.500 ton/day	Above cover is installed

Source: *PLTU* Tanjung Jati B, 2019

3.2. Ambient air quality
Data for TSP concentration of ambient air quality use periodic monitoring, which is carried out every three months by the initiator of the *PLTU* TJB. Data on TSP ambient air quality measurements in the point, as mentioned above in table 2.1, is shown in figure 3.1. Refer to the monitoring data, the average TSP concentration for QU-6, QU-9, and QU-11 is 124,8; 86,82; and 91,88. As for the maximum concentration the concentration is 185,0; 140,0; 138,0, accordingly. The unit is in mg/Nm^3.

3.3. Metrological data

In order to find out the source and direction of the dust trajectory at the sampling location, a wind rose analysis is required. A wind rose analysis was carried out for 2018 and 2019 to see comparisons based on meteorological data from a weather station located at the coal loading jetty. The results of the wind-rose analysis are shown in figure 3 below.



(a) (b)

Figure 3. Windrose analysis: (a) 2018; (b) 2019.

The figure shows that the prevailing wind came from North West and North East, which may affect the site of QU-9 and site of QU-11 in the sampling area. This ocean wind may carry coal dust from the coal yard to the site of QU-9 in particular.

3.4. Dust emission prediction

Emission factors are used for this model verification, obtained from formulas, refer to Vernon, 2017. Only three emission sources are included in this model prediction: coal stockpile (wind erosion), conveyor line emission and stacker-reclaimer operation. There are no leveling activities by HDV machines during field observation. Coal stockpile shape in conical piles has a relatively stable emission rate regardless of the wind direction [6].

Table 3. Emission factor used in the model prediction (TJB 1&2 and TJB 3&4).

No	Activities	Emission Factor	Units	Dust Control Efficiency	Remark	Reference
1	Coal Stockpile	0,0000331	$g/s/m^2$	No control	No water application during sampling period	[7]
2.	Transfer material (conveyor)	0,000099 (TJB 3&4) 0,00016 (TJB 1&2)	$g/s/m^2$	40% with enclosed conveyor belt	Conveyor capacity 1500 tph	[7]
3.	Stacking – Reclaiming (S-R)	0,013	g/s	50% with water suppression	Average wind speed 2,54 m/s. The location of S-R in the middle of coal yard.	[7]

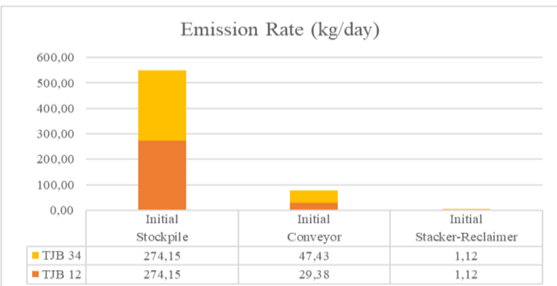
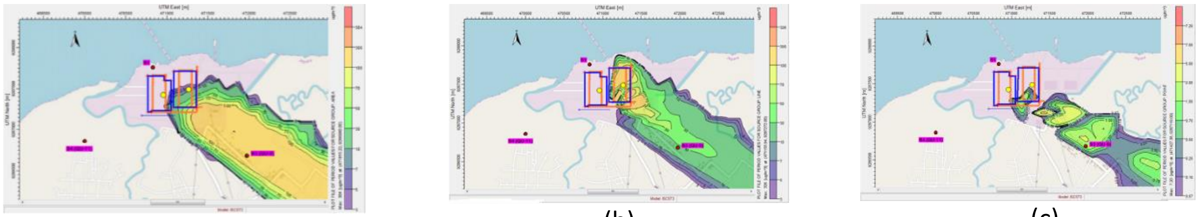


Figure 4. Emission rate from each emission source.

As shown in figure 4, the modeling results contributed from coal stockpiles emissions reached 100 - 200 μg/m^3, followed by conveyor emission reached 30 μg/m^3, and Stacker-Rreclaimer reached 1 μg/m^3. So the main contributor on site 3 is the coal dust stockpile.



(a) (b) (c)

Figure 5. Model prediction of dust emission from coal stockpile.

According to the modeling results in the above figure, it could be identified that the emission contribution from the coal stockpiles is reached 100 - 200 μg/m^3. Meanwhile, the measurement results from secondary data; the average TSP concentration reached 85 - 140 μg/m^3. Based on these results, it can be seen that the forecast of the resulting emissions is close to the actual conditions of the ambient concentration level.

4. Conclusion

Prediction using modeling is able to identify the potential source of dust emission from coal handling management in the coal stockpile area. The most significant source of particulate emissions from the precise operation of coal piling at the *PLTU* is from wind erosion against the coal stockpile's surface. Following the wind-rose analysis and result of modeling using AERMOD, the locations which potentially affected by the coal yard operation of *PLTU* Tanjung Jati B are Station-3 (QU-9/Kaliaman Village) and Station-4 (QU-11/Bondo Village). This is due to the dominant wind direction from the Northwest, namely from the water to the mainland. The potential distribution of particulate concentrations from the coal stockpile has the potential to contribute to particulate contamination in ambient air. Theoretically, it can be seen that the concentration of emissions from coal dust can be controlled. Several control measures include (1) installation of wind-breaks to reduce exposure to wind speeds to reduce the potential for wind erosion on the surface of the coal stockpile, (2) Watering with water either on the stacker-reclaimer or the surface of the coal stockpile, (3) installing a cover on the coal conveyor. It is necessary to perform trace analysis of the particulate sample and back trajectory to identify the amount of concentration and contribution percentage of coal dust.

References

[1] Duan Z, Wang K, Lan Z, Guo Y and Liu Y, 2019 *Chem. Eng. Trans.* **76** 1255–60
[2] Visser G T 1992 *Atmos. Environ. Part A, Gen. Top.* **26(8)** p 1453–60
[3] Mueller S F, Mallard J W and Shaw S L 2009 5.3 Variability Of Natural Dust Erosion From A Coal Pile
[4] DSEWPC 2012 National Pollutant Inventory -NPI- Emission estimation technique manual for Mining version 3.1 JANUARY p. 78
[5] US EPA 2018 User's Guide for the AMS/EPA Regulatory Model (AERMOD) *Epa-454/B-18-001* **EPA-454/B-** p. 1–137
[6] Cong X C, Cao S Q, Chen Z L, Peng S T and Yang S L 2011 *Atmos. Environ.* **45(30)** 5247–53
[7] Vernon A 2017 *Environmental Improvement Program – Particulate Matter Control Best Practice Study June*