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Air particulate matter dispersion at biomass energy plant using AERMOD Modelling

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Abstract. Biomass is included as one of the conventional sources other than solar and hydro energy. There are different types of biomass such as empty fruit bunch (EFB), fronds, mesocarp fibre (MF), trunk and shell. Each type provides a different level of particulate matter and the particulate matter had already emerged as one of the most critical pollutants. The main purpose of this paper is to identify the critical location on-site and to measure and analyse the particulate matter dispersion by using AERMOD Modelling. This paper presents a simulation study of particulate matter dispersion at biomass energy plant. The dispersion of the particulate is studied at Bioenergy plant located at Jengka, Pahang which generates electricity from the EFB waste. The shredded EFB had produced abundant of dust and particulate matter which suspends in the air and deteriorating the air quality. Thus, the dispersion of particulate matter pollutant by the biomass power plant is a rising concern. The influence of other operating variables were studied (temperature, relative humidity, wind speed, wind direction and activity). This paper also compares the concentration of $PM_{2.5}$ and PM_{10} disperse from a location that had been marked as critical. From the result, the average concentration of particulate emitted to the air in 24-hour mean is 0.6944 mg/m^3 for both size. Based on the guidelines provided by the World Health Organization (WHO), the concentration of both $PM_{2.5}$ and PM_{10} are exceeding the level of 24 hour mean of emission and can be concluded as critical.

1. Introduction

Particulate matter has been commonly and frequently referred to as one of six chemicals of air pollutants along with carbon monoxide, lead, nitrogen oxide, ozone and sulphur dioxide. These chemicals are known as toxic pollutants which can cause cancer and other serious health problems or lead adverse environmental effects [1]. In addition, the particulate matter had already emerged as one of the most critical pollutants [2] aside from other elements which already contribute to the pollution. Based on the guidelines of air quality of particulate matter size stated by the World Health Organization (WHO), 24-hour mean of $PM_{2.5}$ and PM_{10} emission are 25 µg/m^3 and 50 µg/m^3.

Based on local source apportionment (SA) studies, the main sources of ambient particulate matter are traffic, industry, domestic fuel burning, natural sources including soil dust (re-suspended) and sea salt and unspecified sources of pollution of human origin [4]. The exposure level towards the particulate matter will determine the health effect like the level of pollution and by the duration of time in which people breathe the polluted air. Furthermore, the burning biomass also releases the particulate matter,

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which also can contribute to variety type of diseases such as pneumonia, cancer, tuberculosis, and asthma [5]. This study was analysed by using AERMOD Modelling Simulation. AERMOD is a steady-state dispersion model developed by American Meteorological Society and U.S EPA due to the consistency of meteorological conditions during the modelling period and horizontally homogenous. This model is designed for stationary sources and emissions. In addition, AERMOD also can handle multiple point, area and volume sources [6].

This paper will compare the concentration of $PM_{2.5}$ and PM_{10} respectively based on on-site particulate matter dispersion from a various location which have been marked as critical. The critical location is decided based on consultation with the plant manager and plant layout of the process plant. The aims of this study are to identify the critical location on-site based on plant layout and particulate matter measurement and analysing the dispersion by using AERMOD Modelling. The data were collected from the Bioenergy Plant and synthesizing the information to estimate the main contributors of ambient PM in the plant.

2. Methodology

2.1. Study Design

The source of particulate matter for this study can be categorized from the industry and domestic fuel burning due to combustion of empty fruit bunch in order to produce the steam for heating purpose. As Malaysia is known as the world's second-largest palm oil producer, we had to consider the waste produced also highest. Furthermore, EFB is produced from 22% of fresh fruit bunch (FFB). With more than 423 mills in Malaysia, our palm oil industry is generated around 80 million dry tons of biomass in 2010 [7]. This study was conducted at the Bioenergy Plant in Jengka, Pahang for one month. The main process of this plant is to generate the electricity and sell it to TNB for the uses of the community around there. To generate the electricity, the EFB was shredded into the fibre and undergo combustion process. The shredded of EFB was obviously visible disperse in the air and potentially as a contributor for the particulate matter emission. The data is collected by using air particulate sampling (APS) and placed at a different location based on the visibility of the shredded EFB disperse in the air. A digital anemometer is used to measure the wind speed and direction on the selected site. The influence of other operating variables were studied (temperature, relative humidity, wind speed, wind direction and activity). This study is about monitoring the ambient air at the Bioenergy Plant.

2.2. Particulate Matter Measurement

The method to measure the particulate matter has followed the guidelines outlined on Chapter 40 of the Code of Federal Regulation (CFR) Part 58, Appendix E (probe and monitoring path siting criteria for ambient air quality). The particulate was measured at the critical point of emission where the biomass dwelt can be visibly seen with our naked eyes. The data was collected after 24 hours from the APS and the filter paper inside the equipment was weighted to measure the difference in mass. The instrument is put at a different place based on rough analysis of the emission. In this study, two of the APS were used to measure the particulate matter size 2.5 microns and 10 microns. Both of the instrument was put at a different location from the emission source.

2.3. Meteorological Data Measurement

AERMOD required the minimum surface of meteorological data like time (year, month, day, hour), wind speed and direction and temperature [8]. The wind speed and direction were measured by using digital anemometer based on the location of the instruments were placed. The device needs to hold high in the air by selecting the measurement option and facing the direction of the wind. Thus, the data of measurements may continue to change as the wind picks up and slow down through gusts of wind. To get the highest calculated wind speed, the max button needs to be pressed and the device would display the values [9]. Besides, anemometer also provided the temperature and relative humidity of the

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surrounding based on the wind flow through it. APS monitor was used to measuring both of particulate matter size 2.5 and 10 microns at a different location. Plus, this monitor was easy to program and operate which was operated by using the battery. This monitor is suitable and has a variety of applications which includes outdoor environmental monitoring and point source monitoring.

2.4. Model Configurations and Input Data

AERMOD was developed from the Industrial Sources Complex Short Term Model (ISCST3) by incorporation more complex algorithms and concepts like the planetary boundary layer (PBL) theory and advanced methods for complex terrains. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain [10]. The time frame of this modelling data was July 10th to 26th until August 9th to 17th. Hourly file emission was important as it was one of the emission data required for model inputs. To include sources data in the model, sources groups and hourly file need to be determined first.

3. Results and Discussion

3.1. Particulate Matter Measurement

Before the data were collected, the location of the critical point was identified and APS were placed at critical points. Table 1 and 2 shows the concentration of $PM_{2.5}$ and PM_{10} from the measurement of the particulate matter. The data were measured and collected after 24 hours of emission and particulate matter emission was calculated.

Table 1. Concentration of $PM_{2.5}$

Activity	**BIOMASS BURNING**					
Date	Wind Speed (m/s)	Wind Direction	Temperature (°C)	Weather	Relative Humidity (%)	Particulate Matter Emission (mg/m^3)
10/7/18	1.17	South West	25.5	Cloudy	73	1.3899
12/7/18	1	South	26	Cloudy	75	0.6944
26/7/18	2	South West	32	Cloudy sunny	60	0.6944
9/8/18	0	South	29	Humid & Overcast	71	1.3899
10/8/18	0	SSW	32	Overcast	53	0.6944
11/8/18	2	SSW	34	Overcast	44	2.0833
13/8/18	1	South	26	Mostly cloudy	69	0.6944
14/8/18	3	South	31	Mostly cloudy	61	0.6944
15/8/18	3	South	34	Mostly cloudy	47	0.6944
17/8/18	1	South East	24	Overcast	90	0.6944

Table 2. Concentration of PM_{10}

Activity	BIOMASS BURNING					
Date	Wind Speed (m/s)	Wind Direction	Temperature (°C)	Weather	Relative Humidity (%)	Particulate Matter Emission (mg/m^3)
10/7/18	0	South West	25.5	Cloudy	73	1.3899
12/7/18	0	South	26	Cloudy	75	1.3899
26/7/18	0	South West	32	Cloudy sunny	60	0.6944
9/8/18	0	South	29	Humid & Overcast	71	0.6944
10/8/18	0	SSW	32	Overcast	53	0.6944
11/8/18	2	SSW	34	Overcast	44	0.6944
13/8/18	0	South	26	Mostly cloudy	69	0.6944
14/8/18	0	South	31	Mostly cloudy	61	1.3889
15/8/18	0	South	34	Mostly cloudy	47	0.6944
17/8/18	0	South East	24	Overcast	90	0.6944

Based on table 1 and 2, the average concentration of particulate emitted to the air in 24-hour mean is 0.6944 mg/m^3 for both size. The data shows a consistent value on the particulate matter emissions as the emission was only dispersed in that area. If we compared the values between the data and guideline provided by the WHO, the particulate matter emitted to the surrounding already exceed the limit.

3.2. AERMOD Dispersion Modelling Results
Figure 1 shows the map of Bioenergy Plant from the satellite view which has been used as a base map. The map was needed to simulate the region of emission. Unfortunately, the cloudy view from above makes the view of plant invisible and not clear.

Figure 1. Base Map of Biomass Energy Plant.

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From the view of the base map, the building parameter and gridded parameter were identified. From there, the simulation generated the 3-dimensional view of the building block. Figure 2 shows the view of the object from the 3-dimensional view of plant layout of biomass energy plant meanwhile figure 3 show the 3-dimensional side view of emission after the model objects which included building parameters, gridded receptors and boundary receptors were identified. The emission was only dispersed at the space (volume) and not harm the citizen but would cause harm to the worker's area there. The dispersion of particulate matter depended on the wind direction and speed. The particle would disperse in the air through the wind and caused long-term effects towards the workers around the location.

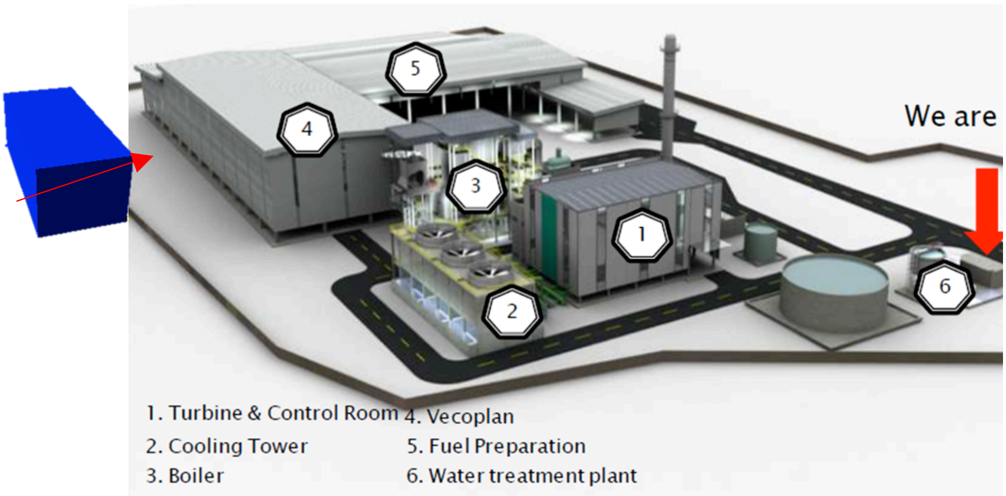
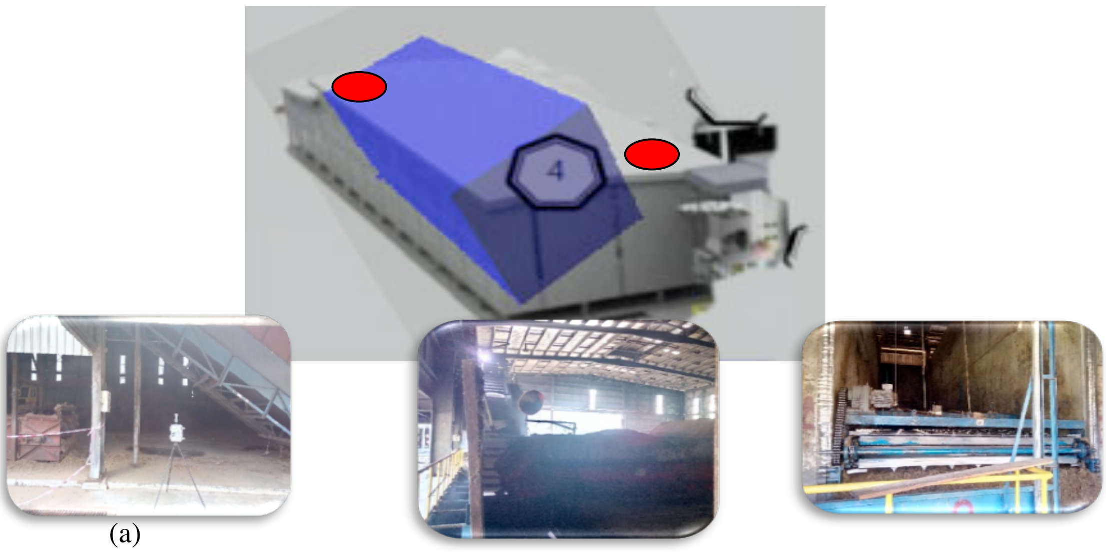


Figure 2. 3 Dimensional View of Emission Sources.



(a) (b) (c)

Figure 3. Parts (a), (b) and (c) show the location of the red dot on the superimpose view of the emission from the sources.

From Figure 3, the 3-D block was generated from the vecoplan. The data inserted in the modelling simulation were indicated the size of vecoplan (63.5 m × 126.11 m). The red circle indicate the critical location of the source of pollution in which included the location of parts (a), (b) and (c). Therefore, the generated 3-D block model has indicated the critically polluted area at the biomass energy plant.

4. Conclusion

This study has shown that AERMOD Model can be used to provide an insight into the surface impact of $PM_{2.5}$ and PM_{10} from the point and major line at annual and hourly averaging periods in model domains within Bioenergy Plant at Jengka, Pahang. This study has highlighted the concentration of particulate matter disperse from the plant. Based on the calculated raw data, the average concentration of particulate emitted to the air in 24-hour mean is 0.6944 mg/m^3 for both size. The average concentration of particulate matter is compared with the guidelines provided by the WHO. From the values, the concentration of both $PM_{2.5}$ and PM_{10} are exceeding the level of 24 hour mean of emission and can be concluded as critical. However, AERMOD Modelling result of simulation does not include certain parameters like weather, relative humidity and temperature. It causes limitations to the results and provides inaccurate data. The analysis of dispersion is done based on the collected data and identify the critical location. The critical location of both particulate matter emission has been identified as both locations located at Vecoplan (Fuel Storage) but at a different work station.

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