Jurnal Pendidikan Teknologi Kejuruan, Vol. 6, No. 2, pp. 163-169, May 2023
e-ISSN 2621-1548; p-ISSN 2621-3273

Total Suspended Particulate (TSP) simulation using the gaussian dispersion model

Yaumal Arbi[*1], Nofriya Nofriya[2], Rahma Fitrianti[2] and Widia Putri[3]

[1] Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Padang, **Indonesia**
[2] Department of Environmental Engineering, Sekolah Tinggi Teknologi Industri Padang, **Indonesia**
[3] Department of Environmental Engineering, Faculty of Engineering, Universitas Andalas, **Indonesia**

*Corresponding Author: yaumalarbi@ft.unp.ac.id
Received 7th May 2023; 1st Revision 12th May 2023; 2nd Revision 23rd May 2023; Accepted 30th May 2023

Cite this https://doi.org/10.24036/jptk.v6i2.33823

Abstract: Air pollution is one of the most dangerous and worrying. One of the causes of air pollution is dust or Total Suspended Particulate (TSP), namely particles with a diameter of <100 μm. The Total Suspended Particulate causes visual distrurbances and respiratory disorders such as URTI (Upper Respiratory Tract Infection). According to data from Badan Pusat Statistik Kota Padang in 2018, URTI represents the highest complaint in the district Lubuk Begalung as many as 5,534 cases (28%). In the district has industrial and transportation activities which are a source of air pollution. However, in there haven't real time monitoring of air pollution, so it is necessary to carry out air pollution simulations. This study aims to determine the concentration of TSP ambient air pollution and to analyze the distribution air pollutant in the Lubuk Begalung District, Padang City. The research method used a quantitative, where the emission inventory and meteorological data used the Gauss dispersion model and surver 15 software. The maximum TSP from measurement and modeling results was 113.42 μg/m^3 and 27.16 μg/m^3. This result explain about the TSP concentration is still below the National BMUA in PP RI No. 41 of 1999, which is 230 μg/m^3 (still in good condition). This is different from previous studies because this study only considers sources of industrial emissions without other sources of pollution. The result of the TSP distribution is moving increasingly towards the Southwest from the emission source and reaches a maximum concentration at the coordinate point (-0.98103 oS, 100.34567 oE), according to the dominant wind direction.

Keywords*:* TSP; Dispersion; Gauss; Surfer; Ambient air pollution

1. Introduction

In 2018, air pollution is the main cause of death for children under the age of 15 which has killed 600,000 people (WHO, 2018). From an economic standpoint, deaths due to air pollution cost an estimated $5 trillion worldwide. In 2019, 90% of the world's population breathed air that exceeded the maximum allowed by WHO, but most of the population worldwide did not have knowledge of air quality information (IQAir, 2020).

One of the pollutants that cause air pollution is particulates or commonly called Particulate Matter (PM). Particulates are divided based on particle size, one of which is dust or Total Suspended Particulate (TSP), namely particles with a diameter of less than 100 μm. According to WHO (2018) particulates can be emitted directly from sources, such as construction sites, unpaved roads, fields, chimneys or fires. Sources of air pollution apart from transportation and office activities mostly come from industrial and housing activities (Sepriani, K.D., 2014). One of the industrial activities in the city of Padang is located on Jl. By Pass which is a multifunctional area, namely residential, industrial and is the main road across Sumatra. Precisely in Kec. Lubuk Begalung, Padang City based on data from the Padang City Statistics Center (2019) there are 2 rubber processing industries and 1 CPO processing industry. Population density in Kec. Lubuk Begalung in 2018 was classified as high, namely 5,907, besides that there were 3 Kindergarten Schools and 2 Elementary Schools which were located close to industrial activities. Based on research by

Ulpah, M. (2015) there is a relationship between ambient dust and symptoms of ARI in toddlers of 61.29% in the working area of Posyandu Kaca Plat with symptoms in toddlers namely fever, cough and dizziness. In addition, the diversity of causes of ARI depends on age, body condition and environmental conditions (WHO, 2018).

According to BPS data for the City of Padang in 2018 ISPA is the highest complaint in the Kec. Lubuk Begalung, namely 5,534 cases or 28% of the total complaints. Currently there is no real time monitoring of air pollution at that location which can describe how much air pollution is due to anthropogenic activities that occur and how the pattern of distribution of the air pollution is generated. However, direct measurement requires equipment, time, and costs that are quite high if it is carried out directly and continuously, so that a simulation of the TSP distribution pattern is carried out. This simulation can be done with statistical calculations using the Gaussian dispersion model. The Gaussian dispersion model is a form of mathematical equation that is converted into variable calculations by adding more detailed pollutant source information for an area being studied (Permatasari, A.I. Ayu, 2014). Pollutant concentrations obtained from the simulation results can be visualized by changing them into contours using surfer15 software. The aim of this research is to determine the concentration of ambient air TSP pollution and to analyze the distribution pattern of air pollutants that occur on Jl. district Lubuk Begalung, Padang City uses the Gauss dispersion model and surfer mapping 15.

2. Methods

This study uses a quantitative approach with a survey approach. The research was conducted by collecting primary data and secondary data. Primary data were obtained from ambient air TSP concentrations, wind speed and air temperature at the sampling location during sampling. The secondary data of this research are meteorological data (wind direction and speed) from BMKG data from Padang City, data on sources of pollution (physical data on chimneys, TSP concentration data), as well as maps of sources of pollution from the Padang City Environment Agency (DLH). Direct measurements of ambient air were carried out at 3 points in Kec. Lubuk Begalung. Selection of locations for points I, II and III based on SNI 19-7119.6-2005 concerning determination of locations for sampling for ambient air quality monitoring tests. The location of point I is to the west of the emission source location while point II is to the east of the emission source location. The location of point III is towards the southwest of the emission source, this direction is in accordance with the dominant wind direction of Padang City. More details on the location of the sampling points can be seen in Figure 1. Sampling was carried out for 4 (days), namely October 28 2020 to October 31 2020. TSP measurements were carried out for 24 hours at each point. Measurements were carried out using High Volume Autosampler (HVAS) equipment in accordance with SNI 7119-3-2017 with the Gravimetric method. The results of measurements and calculations using Gauss modeling are visualized in contour form using Surfer 15 software.

Figure 1. Map of the location of sampling points
(red dots are sampling locations, yellow dots are emission sources)

3. Results

TSP measurement in ambient air at 3 different points. The three locations are determined based on SNI 19-7119.6-2005, namely east, west and southwest of the emission source. TSP concentration data obtained from direct measurements can be seen in Table 1.

Table 1. TSP concentrations in ambient air

Point	Coordinate Point	Concentration TSP (μg/m³)
Point I	-0.958910 ° S 100.409918 ° E	83,6
Point II	-0.961673 ° S 100.400546 ° E	106,9
Point III	-0.965628 ° S 100.399056 ° E	113,4

Based on table 1, it is known that the highest concentration is at point III, which is southwest of the emission source of 113.4 μg/m^3, 106.9 μg/m^3 at point II to the west of the emission source, while to the east of the emission source or point I is 83.6 μg/m^3. Sampling locations at points I and III are on the football field in the residential area, while at point II the location is on vacant land surrounded by residential houses which are free from disturbances. The results obtained from the measurements show that the concentration of TSP in areas that are in the same direction as the dominant wind direction (point II and point III) is higher than in other directions (point I).

TSP measurements are carried out according to SNI 19-7119.3.2005, namely by using a filter to accommodate the air sucked by the pump. The filter used in this method has a porosity of 0.3 μm to < 100 μm when the flow rate is set to 1.13 - 1.70 m^3/minute. In this condition, the particulate obtained is TSP, this is in accordance with Peavy's theory (2013) that dust (TSP) has a diameter size of between 1 - 100 μm. When compared with previous studies which stated that the concentration of TSP for urban areas (the Lubuk Begalung area) in 2008 was above BMUA, which was 245.050 μg/m^3 (Hafidawati, 2007). Likewise, in 2006 the concentration of TSP for a total of 24 hours in the Lubuk Begalung area exceeded the BMUA PP RI No 41 of 1999, namely 270.923 μg/m^3 (Oktavia, Sri, 2006). Thus, the results obtained from this study are different from the results obtained previously. This is because in this study the sampling location was carried out in a residential area and did not take into account the source of transportation emissions by sampling ambient air in accordance with SNI 19-7119.9-2005 concerning sampling for roadside air quality monitoring tests. The results of some of these studies also indicate a decrease in the concentration of TSP pollution that occurred in the Lubuk Begalung area.

Meteorological data used in this modeling was obtained from BMKG which was downloaded via the website www.dataonline.bmkg.go.id. The data is taken from the Teluk Bayur station which is the closest station. Meteorological data used are wind direction and speed to determine the dominant wind direction, air temperature and solar radiation to determine the value of atmospheric stability. The data analysis used is data from 2016 - 2020. Calculation of TSP concentrations using the Gauss model was carried out at the height of the scattering and the maximum dust concentration was at an average human height of 1.5 meters from the ground. The concentration of TSP in the Gaussian model is strongly influenced by the dominant wind direction in an area. The results of meteorological analysis in Lubuk Begalung District average wind direction is 1 m/s at a dominant temperature of 27.1^{0}C to the southwest with atmospheric stability class B (unstable). Under these conditions, in general, the spread of TSP can occur up to thousands of meters or even tens of kilometers from the source with concentrations that will increase to the maximum distance, then the concentration of TSP will be smaller the further the distance is spread.

Based on the calculation of the TSP generated at each different emission source, this also results in the distribution of TSP in the ambient air to be different at each receiving point. In this study, three different emission sources were calculated, namely boilers (refrigeration), dryers (dryers) and generators (power plants). From the results of the contour analysis, it was found that for source A (boiler) the resulting distribution of TSP reached normal ambient air (at a height of 1.5 meters) at a distance of 400 meters from the source with a TSP concentration of 0.05 μg/m^3. This is closer than the emission sources of other dryers and generators. Emission sources with dryer type are represented by source B, source F and source G where the average distribution of TSP with concentrations > 0.01 μg/m^3 begins to fall in ambient air at a distance of 800 meters from the emission source. Emission sources with generator type are represented by source C, source D, source E, source H and source Ibaru after a distance of 1800 meters from the emission source experienced an increase in TSP in ambient air of > 0.01 μg/m^3.

TSP pollution modeling in this study was carried out with a maximum distance of the receiver (x) is 10 km from the source. Calculation of the highest TSP concentration was obtained at each receiving point with a crosswind distance (y) = 0 m and a downwind distance (x) from 0 - 10,000 m in multiples of 200 m. In calculating the Gauss model, the concentration of TSP is obtained using the distance in the same direction as the dominant wind direction, namely to the southwest from the emission source. The maximum distance of TSP concentration distribution is influenced by the effective emission height which is obtained from the sum of the height of the chimney and the height of the plume rise. The higher the value of the effective height, the farther the maximum distance of the TSP spread from the source. For more details can be seen in Figure 2.

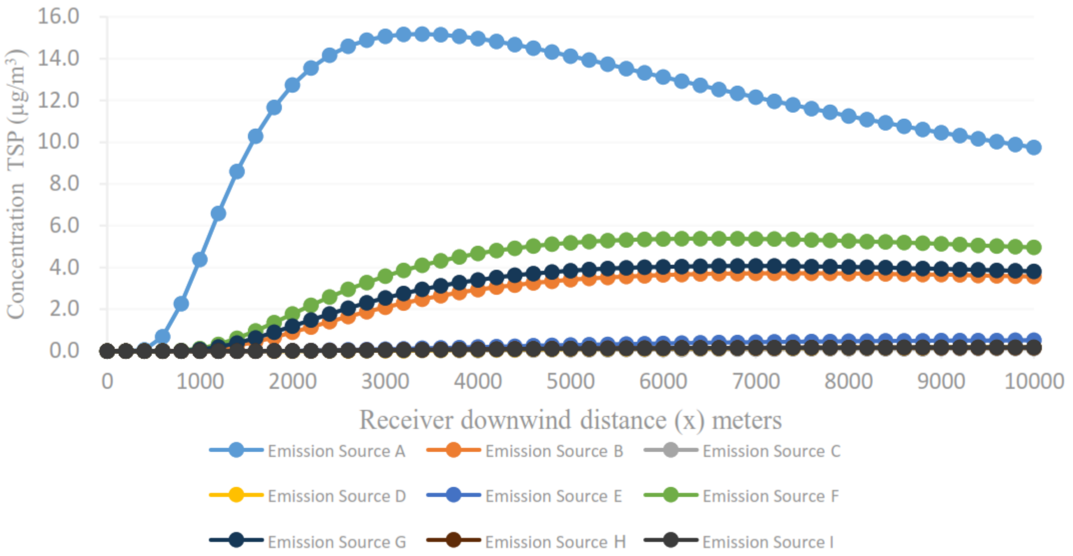

Figure 2. Graph of calculation results of TSP concentration with downwind distance

Based on Figure 2. it can be seen that the highest TSP concentration came from source A, namely 15.178 μg/m^3 at a distance of 3,400 meters from the source, then decreased the further away from the source. The pattern of decreasing TSP concentrations after reaching the maximum value also occurred in the distribution at source B, source F and source G, with the highest TSP concentration values being 3.724 μg/m3 at a distance of 7400 meters from the source, 5.385 μg/m^3 at a distance of 6400 meters from the source and 4.073 μg/m^3 at a distance of 6800 meters from the source. This indicates that TSP pollution at sources A, B, F, and G still occurs in the study area or is still within a 10 km radius.

4. Discussion

Based on previous research by Andriansyah, B, 2019 it was stated that pollutant concentrations increased to a maximum concentration at a distance of 1600 m from the source and decreased further up to a distance of 5000 m. In Silvia's research, 2013, it was stated that the amount of activity that occurred also affected the concentration of TSP obtained, this was in accordance with previous studies which stated that the increase in factory production rates and activities or activities that occurred had an impact on air quality. This is consistent with the results of this study, namely the concentration of TSP pollution as a result of the calculation will increase and reach a maximum point and then decrease again, as in the ambient air TSP concentration from emission source A, the maximum concentration is 15,718 μg/m^3 at a distance of 3,400 m and then decreased, so did the concentration of TSP from other sources. In addition, this study also supports the theory of meteorological factors affecting the value of pollutant concentrations, which can be seen in the concentration of TSP at the H source which has accumulated/slowly increased by 0.0002 μg/m3 after 200 m under conditions of low wind speed, namely an average of 1m/s. This study proves that the emission rate is directly proportional to the concentration of TSP pollutant, which can be seen from the highest concentration, namely 15.718 μg/m^3, produced by emission source A, with an average during 2016-2020 producing the largest concentration of TSP emissions, namely 139.39 mg/Nm^3, this value is far above the TSP concentration from other sources which average <60 mg/Nm^3. The concentration of TSP in ambient air calculated using the Gauss model is compared with the results of previous measurements. The results of the comparison of TSP concentrations in ambient air can be seen in Figure 3.

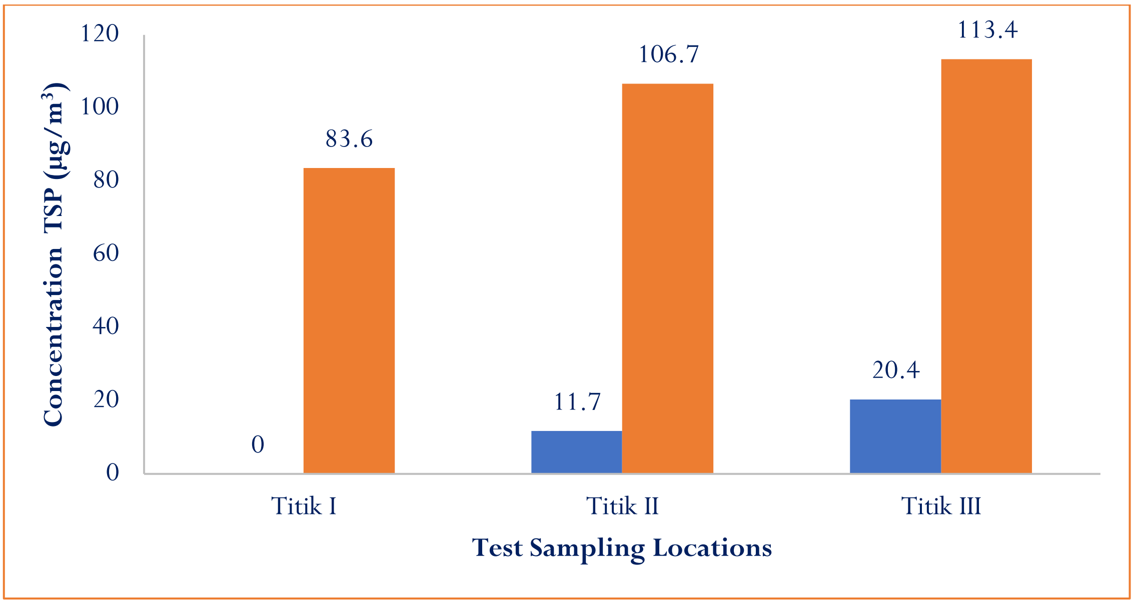

Figure 3. Comparison of TSP concentrations in ambient

Based on the analysis of Figure 3, it can be seen that the measurement ambient concentration and the calculation results have a large difference in value. At the concentration of TSP the measurement results have a greater value than using the Gauss model calculation. One of the factors that causes the difference is that in the calculation of the Gauss model the direction and wind speed are considered to have no change or constant, namely 1 m/s to the southwest, while in field measurements the wind speed is the same as 1 m/s but the wind direction that occurs is to the east of the source.

In addition, in the calculation of the Gauss model, the factors that affect ambient air concentrations only come from emission sources in the calculations of this study without taking into account other emission sources, such as industrial emission sources that are not included in the calculation, motor vehicle fumes, road dust and others. It can be seen at point I in the calculation results that the TSP concentration in the ambient air is 0 μg/m³, while the direct measurement results show a TSP concentration of 83.6 μg/m³. This is because in the Gaussian model it is assumed that the concentration of TSP is only influenced by sources A, B, C, D, E, F, G, H and I, while emissions from these sources only move towards the southwest of the source, so that in point I which is the eastern ambient air from the source is not affected by any TSP deployment. However, in reality Point I already has a TSP value of 83.6 μg/m³ which is the concentration of TSP already in the ambient air without being affected by emission sources A, B, C, D, E, F, G, H and I.

At point II based on the calculation results obtained a value of 11.7 μg/m³ and from field measurements obtained a result of 106.9 μg/m³. At point III the measurement results were 113.4 μg/m³ and the calculation was 20.4 μg/m³. This stated that the difference between the two was very large, but seen from the results of point I analysis which stated that the ambient air at the study site already had TSP pollution of 83.6 μg/m³ before experiencing influence from sources A, B, C, D, E, F, G, H and I, the difference in TSP concentration at point II between calculations and field measurements is 23.3 μg/m³ and at point III of 9.4 μg/m³. The results of the analysis concluded that all calculated TSP concentrations were smaller from the results of field measurements, this is in accordance with the Gaussian model simulation theory according to Colls (2009), a model that is influenced by the wind speed vector and pollutant concentration only, without regard to other emission vectors. . There are differences in the results of TSP concentrations from measurement results and modeling which are strongly influenced by the topographic conditions of sampling. From the results of the comparison, it is known that air emissions from industrial sources in Lubuk Begalung District do not have a significant effect on TSP concentrations in ambient air in Lubuk Begalung District.

This is also consistent with previous research that the measured TSP concentration was greater than the calculated TSP concentration, namely 50.93 μg/m³ TSP measured while the calculated result was 1.19 μg/m³ (Zellia, et al. 2018). This proves that in modeling, the TSP pollutants obtained only come from emission sources, but in field measurements TSP is heavily influenced by other emission sources (activities of surrounding industries, residents and motorized vehicles even though the measurements are carried out far from the main road). The concentration of TSP in Lubuk Begalung District, both based on calculations and the results of field measurements, both show results that are still below the National BMUA attached to Government Regulation Number 41 of 1999, which is 230 μg/m³. This indicates that TSP pollution in the Lubuk Begalung Sub-District is still in good condition, seen from the accumulation of industrial sources and from other emission sources.

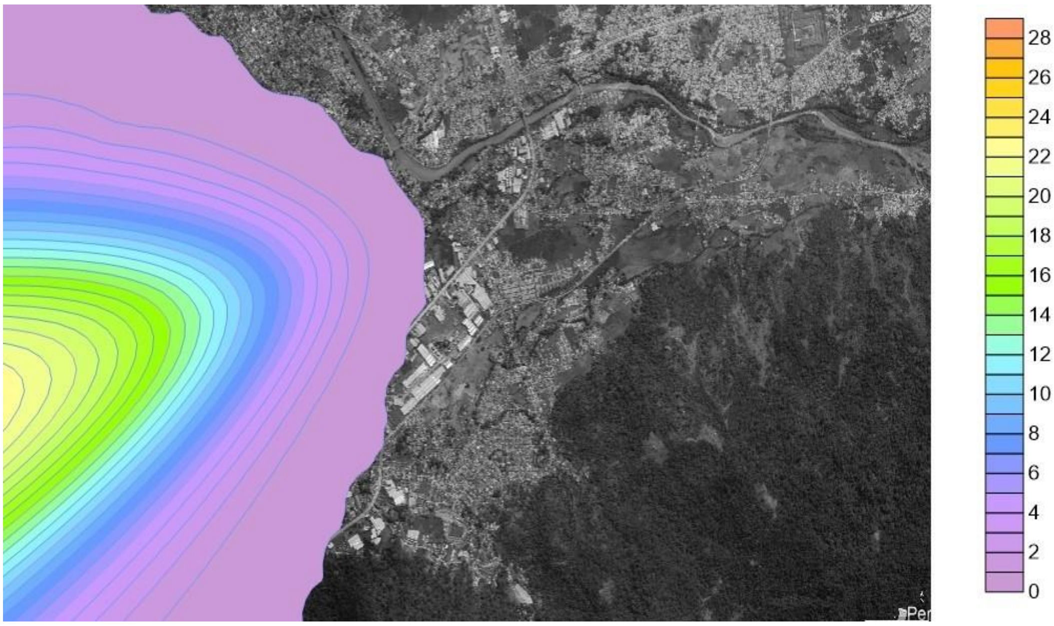

Figure 4. Contour of total concentration of TSP in Lubuk Begalung District

TSP concentration contours are obtained using overlays with maps from google earth and Surfer software. The concentration scale is depicted with purple (low concentration) to orange (high concentration) gradations with the use of a different scale on each contour to make it easier to read changes in concentration. The yellow circle is used to mark the emission source point. In Figure 4, the accumulated distribution of TSP is calculated from point A to the southwest according to the dominant wind direction. In Figure 4.14 it can be seen in the research area that the distribution of TSP is moving up in the direction of the dominant wind (towards the Southwest) and continues to increase to the range of 22-23 μg/m³. Based on the results of the calculation of the accumulation of TSP distribution concentrations in Lubuk

Begalung District, TSP concentrations continued to increase and were highest at the coordinate points (-0.981030S, 100.34567 0E) with a value of 27.1628 μg/m^3.

According to Vissher (2014), the Gaussian plume model explains the relationship between pollutants emitted from sources and pollutant concentrations in ambient air. In this model, it is assumed that the shape of the smoke puffs corresponds to the direction of the wind (x-axis) and the wind speed and direction are assumed to be constant, so that it is homogeneous and the concentration of pollutants will move normally. According to Sepriani (2014), the distribution of pollutant particulates spreads from the west to the east according to the prevailing wind direction. This is supported by research conducted by Zellia in 2018 which states meteorological factors such as wind speed, temperature and air humidity play an important role in determining the level of air pollution. This is in accordance with the results of this study that TSP spreads to the southwest according to the dominant wind direction in the study area.

5. Conclusion

Ambient air TSP pollution in Lubuk Begalung sub-district by Gauss modeling is the maximum 27.16 μg/m^3. Meanwhile, based on measurement results the largest TSP concentration obtained is 113.42 μg/m3. The results of the maximum TSP concentrations for both were still below the National BMUA in PP RI No. 41 of 1999, which was 230 μg/m^3. This indicates that the concentration of TSP pollution in Lubuk Begalung District, Padang City is still in good condition and air emissions from industrial sources do not significantly affect TSP concentrations in ambient air. Based on the Gaussian model simulation, at a distance of 10,000 meters the accumulated TSP concentration increases according to the dominant wind direction (to the southwest) and continues to increase to the range of 22-23 μg/m^3. The spread of TSP extends vertically and horizontally according to the dominant wind direction, namely to the southwest with concentrations increasing up to a maximum concentration of 27.1628 μg/m^3 at coordinate points (-0.98103 0S, 100.345670E).

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