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Comparison of Dustfall and Total Suspended Particulate Generation from Latosol Soil from Padang and Bandar Lampung Municipalities

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Abstract

One of the main environmental pollution is air quality deterioration caused by the generation of dustfall and TSP from soil surface. The purpose of this research was to measure dustfall and TSP generation from Latosol soil in Padang and Bandar Lampung municipalities, to analysis the correlation between dustfall and TSP generation as affected by wind speed, soil moisture content and land cover and to determine emission factor of dustfall and TSP generation. The study was conducted based on SNI 13-4703-1998 and SNI 19-7119.3-2005. Result of the average generated dustfall of Latosol soil from Bandar Lampung Municipality was about 5 tons/km^2.month and for Latosol soil from Padang city was 4 ton/km^2.month. Result of the average generated TSP for Latosol soil from Bandar Lampung City was 36 μg/Nm^3 and for Padang city was 32 μg/Nm^3. Generation of dustfall and TSP Latosol soil from Bandar Lampung City was higher than Padang City. The wind speed positively correlated with dustfall generation, while the soil moisture content and land cover was negatively correlated with dustfall generation. The result of emission factors is a form of simplification to determine the dustfall and TSP generation from field.

Keywords: dustfall, emission factor, Latosol soil, total suspended particulate

INTRODUCTION

Increase of industry and transportation activity causes higher concentration of gases or pollutants. This resulted in air pollutants air pollution. Air pollution causes decrease of environmental quality and health problems in humans. The main environmental pollution is the degradation of air quality that is caused by the dustfall and total suspended particulate (TSP) generation from soil surface (Yuwono *et al*. 2017). Based on the research of Amaliah *et al.* (2014), negative impact of dustfall generation of Entisol soil on human health allegedly higher than Andisol soil because size fine particles on dustfall Entisol soil are high (63.7%), so that such particles can be stored in alveoli and disrupt respiratory system.

Some research has been conducted regarding the dustfall and TSP generation using some type of soil. Research conducted by Rochimawati (2014), TSP generation of Inceptisol (Latosol) soil from Dramaga, Bogor was 101-187 µg/m^3 at wind speed 0.9-1.5 m/sec and soil moisture content 28.9-31.2%. Based on research of Amaliah (2013), dustfall and TSP generation of Inceptisol soil positively correlated with wind speed and negatively correlated with soil moisture content and land cover. More research about dustfall and TSP generation needs to be done from the same soil type but comes from a different location. The results obtained can be used to determine emission factors of dustfall and TSP based on specific soil type. The purpose of this research was to measure dustfall and TSP generation from Latosol soil in Padang and Bandar Lampung municipalities, to analysis the correlation between dustfall and TSP generation as affected by wind speed, soil moisture content and land cover and to determine emission factor of dustfall and TSP generation.

MATERIALS AND METHODS

The instruments used during the experiment were a dustfall canister [AS-2011-1], High Volume Air Sampler [HVAS, Staplex-USA Model TFIA-2], filter paper [1.6 µm, Whatman #1820-110], tunnel [7.8 m length, 0.76 m width, and 2.4 m height], blower [Hercules; Ø = 24"; 220V; 50 Hz; 170 W], air velocity meter [VELOCICALC 8357-TSI], digital soil moisture tester [OGA Model TA-5], universal oven [UNB 400], timer, analytical balance [OHAUS; Adventurer Pro], and Petri dish [Ø = 80 mm]. The materials used were distillate water and Latosol soil samples from Padang and Bandar Lampung municipalities.

Dustfall and TSP generation simulation conducted in two tunnels with the same size. Dustfall and TSP generation measurement conducted during 13 days with the blower operating time for the dustfall was 11 hours and TSP was 1 hour. Measurement of dustfall generation is using dustfall canister. Measurement of total suspended particles using HVAS with flow rate correction as four times in one hour at minute to 1, 20, 40 and 60.

The measurement of the wind speed was conducted on every day on the morning and afternoon for dustfall and only in the morning for TSP. Measurement conducted on the side of the tunnel with three spot in the left, centre and right to get the average of wind speed. Correlation between dustfall and TSP generation with wind speed obtained by making the other factors that is soil moisture content land cover was constant.

Soil moisture content measurement conducted on every day, on the morning at 06.00-07.00 am and the afternoon at 05.00-06.00 pm for dustfall and TSP. Soil water content was arranged with watering the soil with water then stir manually until the soil moisture content was equitable. Soil moisture content that is used is 22%, 15% and 8% for dustfall and TSP generation.

Correlation between dustfall and TSP generation with soil moisture content obtained by making the other factor that is wind speed and land cover was not applied.

Correlation of dustfall and TSP generation with land cover conducted during four days with making the other factors that is wind speed and soil moisture content was constant. Land cover that is used is paddy plant with average height was 15 cm has been aged 2 weeks. Land cover is applied on tunnels which at 10%, 20%, 30% and 40% of the surface area of the land in the tunnel with the spatial distances between the caps are equal.

Dustfall Generation Measurement

The Requirements in measuring dustfall concentration set by Indonesian Standard namely SNI 13-4703-1998 about Determination of Dust Generation in the Air with Dustfall Catcher. Dustfall generation obtained by using Equation (1).

$$C = \frac{W_2 - W_1}{A} \times \frac{30}{T} \qquad (1)$$

Where:

C	:	dustfall generation in the ambient air (ton/km^2.month)
W_2	:	final weight of filter paper (ton)
W_1	:	initial weight of filter paper (ton)
A	:	surface area of dustfall canister (km^2)
30	:	number of days in month
T	:	measurement elapse time (day)

TSP Generation Measurement

Generation of TSP was measured according to SNI 19-7119.3-2005 about Test Method for Total Suspended Particles Using High Volume Air Sampler (HVAS) Equipment with gravimetric method. TSP generation obtained by using Equation (2), (3), (4), (5), and (6).

$$Qc = Qs \times \left(\frac{Tr}{Ta}\right) \qquad (2)$$

$$V = Qc \times t \qquad (3)$$

$$Vr = V \times \left(\frac{P}{760}\right) \times \left(\frac{298}{Tr + 273}\right) \qquad (4)$$

$$C_1 = \left(\frac{W_2 - W_1}{Vr}\right) \qquad (5)$$

$$C_2 = C_1 \times \left(\frac{t_1}{t_2}\right)^{0.185} \qquad (6)$$

Where:

Qs : flow rate on test (m^3/minute)

Qc : corrected flow rate (m^3/minute)

Tr : room temperature on test (℃)

Ta : tool temperature (℃)

P : atmospheric pressure (mmHg)

V : volume of air samples (m^3)

Vr : volume of standard air samples (m^3)

t : measurement elapse time (minute)

C_1 : momentary concentration (μg/Nm^3)

W_2 : final weight of filter paper (gram)

W_1 : initial weight of filter paper (gram)

C_2 : standard concentration (μg/Nm^3)

t_1 : momentary exposure time (hour)

t_2 : standard exposure time (hour)

Emission Factor Formulation

The conventional analysis was used to determine emission factors of dustfall and TSP. This analysis is based on research of Yuwono *et al*. (2014). Based on Yuwono *et al*. (2016), the emission factors of TSP as affected by wind speed, soil moisture content, and percentage of vegetation cover have been developed and readily implemented in the field as a tool for air quality change assessment. Emission factors formulation of dustfall and TSP is according with general pattern of the conventional regression. Equation (7) and (8) is a form of general equation used in conventional analysis methods.

$$E_{DF} = dU^x + eM^y + fL^z \qquad (7)$$

$$E_{TSP} = dU^x + eM^y + fL^z \qquad (8)$$

Where:

E_{DF} : emission factor of dustfall (ton/km^2/month)

E_{TSP} : emission factor of TSP (μg/Nm^3)

d, e, f : linear influence coefficient

x, y, z : polynomial coefficient

U : wind speed (m/s)

M : soil moisture content (%)

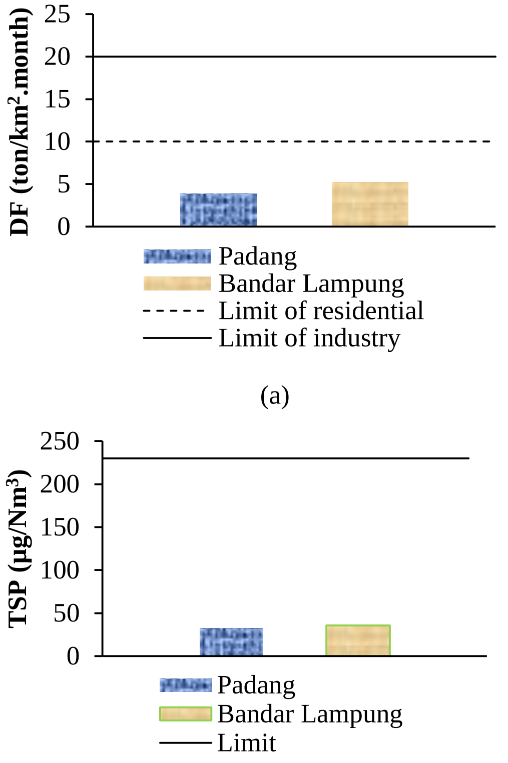
L : land cover (%)

RESULT AND DISCUSSION

Dustfall and TSP Generation

Measurement of dustfall and TSP generation was carried out in a laboratory scale tunnel with variation of wind speed, soil moisture content, and percentage of land cover. Based on Indonesian Government Regulation (PP 41/1999) about Air Pollution Control, quality standard of dustfall generation for residence and industry are 10 ton/km^2/month and 20 ton/km^2/month, respectively. Meanwhile, quality standard of TSP are 230 μg/Nm^3. The result of measurement dustfall generation from Bandar Lampung and Padang municipality indicated that average dustfall generation from Latosol soil did not exceed the quality standard for residence and industry. Average dustfall generation of Latosol soil from Bandar Lampung municipality was 5 ton/km^3.month, meanwhile dustfall generation of Latosol soil from Padang municipality was 4 ton/km^2.month. Average TSP generation of Latosol soil from Bandar Lampung and Padang Municipality also did not exceed quality standard. TSP generation of Latosol soil from Bandar Lampung and Padang Municipality amounted to 36

μg/Nm^3 and 32 μg/Nm^3. Comparison of dustfall and TSP generation of Latosol soil from Padang and Bandar Lampung municipality presented by Figure 1.



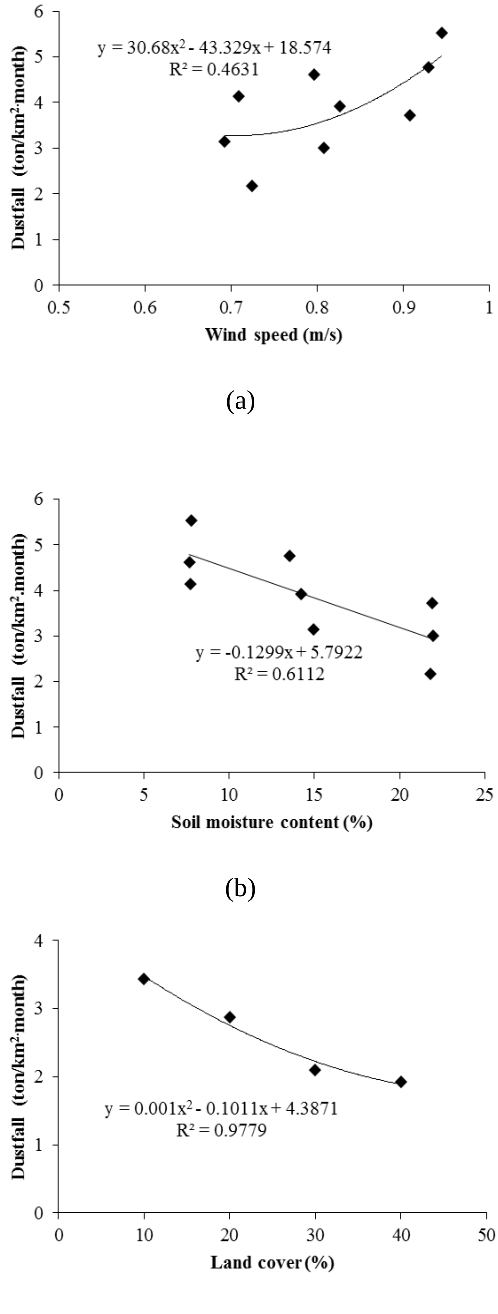
(b)

Figure-1. Dustfall (a) and TSP (b) generation of Latosol soil.

Dustfall and TSP generation of Latosol soil from Bandar Lampung City is bigger than Padang City. Analytical result of Latosol soil texture from Padang City obtained that the content of sand is 14.3%, dust is 22.6%, and clay is 63.1%, meanwhile for the content of sand, dust, and clay from Bandar Lampung City are 16.8%, 19.2%, and 64.0%. Based on Azmi *et al.* (2015), the bigger of sand fraction (larger particles) in a particular type of soil, the greater the generation of dustfall. In the quiet atmosphere, a small-sized particulate matter (PM_{10} and $PM_{2.5}$) takes a day's up to years for dust to settle out and it can be carried over distances of more than 1000 km, but it can be washed out by rain very quickly (Kruell *et al*. 2013).

Correlation Analysis of Dustfall and TSP of Latosol Soil from Padang City

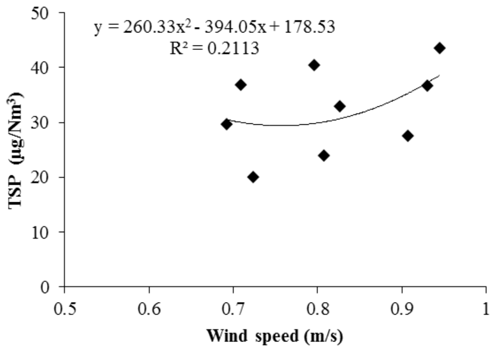
Naturally dustfall and total suspended particulate (TSP) can be generated from dry soil that carried away by the wind. Wind speed can lead to lift fine particles from the soil surface until produce dustfall. Wind speed measured value was 0.7-0.9 m/s. Dustfall and TSP generation of Latosol soil from Padang city positive correlation with wind speed. Wind speed increasing can increase generation of dustfall and TSP. According to Liu *et al.* 2004, the relationship between wind speed and dust storm occurrence is well documented since wind is the driving force for dust and sand deflation and transport. Dustfall generation of Latosol soil from Padang city in ambient air is presented in Figure-2.



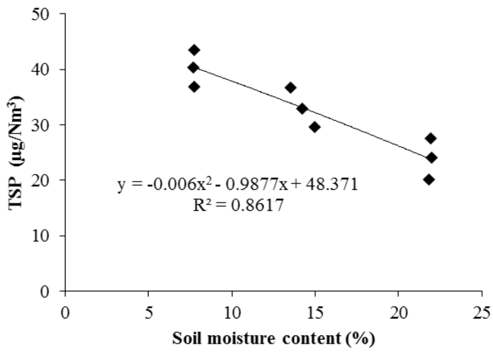
(c)

Figure-2. Dustfall generation of Latosol soil from Padang city as affected by wind speed (a), soil moisture content (b), and land cover (c).

Correlation of dustfall and TSP generation with soil moisture content and land cover is negative. This result according with research of Hamiresa *et al.* (2016), Rochimawati *et al.* (2014), and Yuwono *et al*. (2017), that the higher the soil moisture content and land cover so generation of dustfall and TSP is lower. Dust index in the eastern part of China can be understood from the fact that the dry background, dry-cold surge, and strong cyclone winds are favourable for causing the dust storm or for forming dust weather (Qian *et al.* 2001). TSP generation of Latosol soil from Padang city is presented in Figure-3.



(a)



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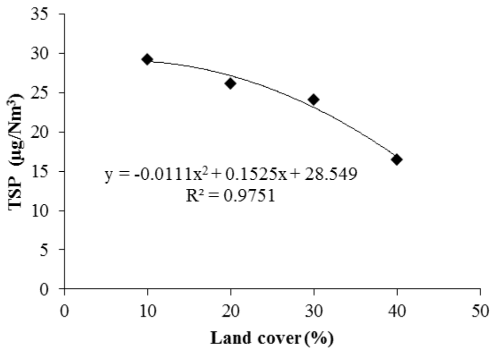


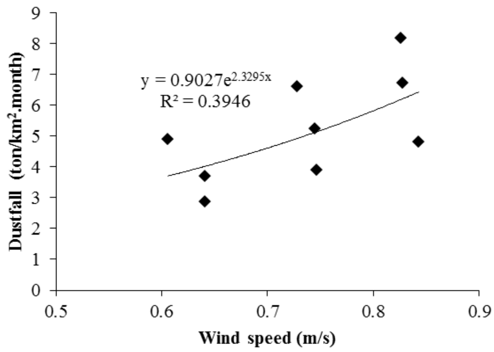
(c)

Figure-3. TSP generation of Latosol soil from Padang city as affected by wind speed (a), soil moisture content (b), and land cover (c).

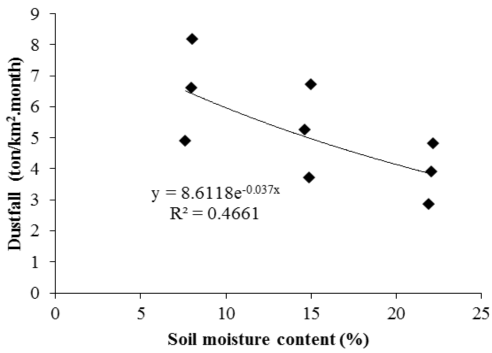
Land cover can maintain soil moisture until the soil becomes more compact and dust reduced (Liu *et al.* 2004). According to Tegen *et al.* (2002), dustfall emissions from the Sahara are reduced by 4% as a result of taking vegetation phenology into account. Dense shrub lands planting can reduced dustfall emissions by 27% from Asia and Australia. Vegetation increase in the sensitive areas evidently decreases dust storm frequency and blowing dust frequency, but it exerts a weak influence on the floating dust frequency (Mao *et al*. 2013).

Correlation Analysis of Dustfall and TSP of Latosol Soil from Bandar Lampung City

Wind speed measured value was 0.6-0.8 m/s. Based on this research, dustfall and TSP generation of Latosol soil from Bandar Lampung city is positive correlation with wind speed. This result show that dustfall and TSP generation is affected by wind speed. Based on research of Laurent *et al.* (2006), dustfall concentration is affected by surface aerodynamic roughness, soil dry size distribution, texture, wind speed, soil moisture, and snow cover. Dustfall generation of Latosol soil from Bandar Lampung city in ambient air is presented in Figure-4.



(a)



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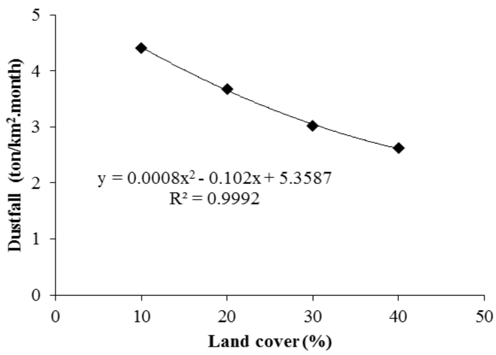
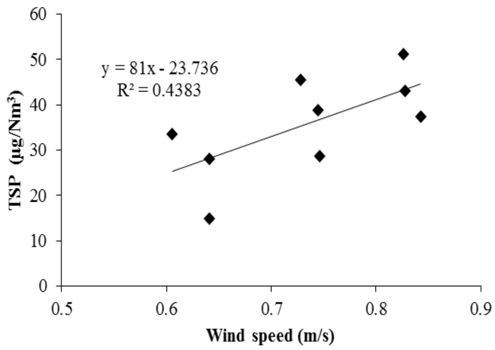


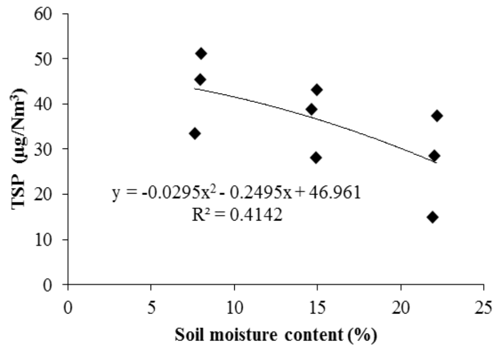
(c)

Figure-4. Dustfall generation of Latosol soil from Bandar Lampung city as affected by wind speed (a), soil moisture content (b), and land cover (c).

Dustfall and TSP generation is negative correlation with soil moisture content and land cover. This is show that dustfall and TSP generation is affected by soil moisture content and land cover. The soil moisture effect on the wind threshold can be considered identical for all soil textures and similar to that observed for sands, once the fraction of the soil moisture, which does not affect the reinforcement of the soil cohesion, has been subtracted (Fecan *et al.* 1999). TSP generation of Latosol soil from Bandar Lampung city is presented in Figure-5.



(a)



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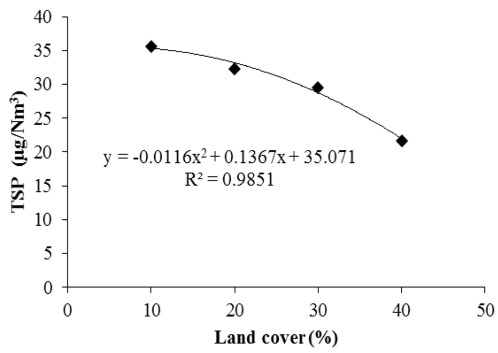

(c)

Figure-5. TSP generation of Latosol soil from Bandar Lampung city as affected by wind speed (a), soil moisture content (b), and land cover (c).

The increase of land cover shows that land cover negatively correlated with dustfall generation. This can mean that regions with higher land cover then dustfall generation will lower. (Yuwono *et al.* 2015). According to Bacon *et al*. (2011), one potential factor that can significantly control the dust emission is protection of the soil from wind erosion (Aeolian) such as with addition of vegetation.

Emission Factors

Emission factor equations are compiled based on the value of the higher coefficient of determination (R^2). $E_{DF.Pad}$ is emission factor of dustfall for Latosol soil from Padang city. $E_{TSP.Pad}$ is emission factor of TSP for Latosol soil from Padang city. $E_{DF.BL}$ is emission factor of dustfall for Latosol soil from Bandar Lampung city. $E_{TSP.BL}$ is emission factor of TSP for Latosol soil from Bandar Lampung city.

$E_{DF.Pad} = (30.7U^2 - 43.3U + 18.6) \times 0.3 + (- 0.1M + 5.8) \times 0.3 + (0.001L^2 - 0.1L + 4.4) \times 0.4$

$E_{TSP.Pad} = (260.3U^2 - 394.1U + 178.5) \times 0.2 + (-0.006M^2 - 1.0M + 48.4) \times 0.4 + (-0.01L^2 + 0.2L + 28.6) \times 0.4$

$E_{DF.BL} = (0.9e^{2.33U}) \times 0.3 + (8.6e^{-0.04M}) \times 0.3 + (0.0008L^2 - 0.1L + 5.4) \times 0.4$

$E_{TSP.BL} = (81U - 23.7) \times 0.3 + (-0.03M^2 - 0.2M + 47.0) \times 0.3 + (-0.01L^2 + 0.1L + 35.1) \times 0.4$

The results of the emission factor formed to simplify the determination of dustfall generation and TSP in the field. The data have been produced between field measurements and laboratory tests can be different due to the other factors that can affect the results of dustfall and TSP generation, i.e. wind speed and unstable soil moisture content, human activity, buildings, type of land cover, topography of the location the existence of soil types and other meteorological factors (Armando 2016). Those emission factors can at this point be implemented directly in the field as an approach to predict the quantitative impact of any activity such as land clearing, construction site preparation, deforestation and so forth, on air quality deterioration due to land surface cover change by simply inputting local prevailing wind speed and average soil moisture content (Yuwono *et al.* 2014).

CONCLUSIONS

Based on the research, there were three conclusions as follows:

1. Result of the average generated dustfall of Latosol soil from Bandar Lampung Municipality was about 5 tons/km^2.month and for Latosol soil from Padang city was 4 ton/km^2.month. Result of the average generated TSP for Latosol soil from Bandar Lampung city was 36 µg/Nm^3 and for Padang city was 32 µg/Nm^3.
2. Dustfall and TSP generation of Latosol soil from Bandar Lampung and Padang municipalities positively correlated with wind speed, while dustfall and TSP

generation was negatively correlated with soil moisture content and land cover.

3. Emission factors

   a. Dustfall generation of Latosol soil from Bandar Lampung city

   $E_{DF.BL} = (0.9e^{2.33U}) \times 0.3 + (8.6e^{-0.04M}) \times 0.3 + (0.0008L^2 - 0.1L + 5.4) \times 0.4$

   b. TSP generation of Latosol soil from Bandar Lampung city

   $E_{TSP.BL} = (81U - 23.7) \times 0.3 + (-0.03M^2 - 0.2M + 47.0) \times 0.3 + (-0.01L^2 + 0.1L + 35.1) \times 0.4$

   c. Dustfall generation of Latosol soil from Padang city

   $E_{DF.Pad} = (30.7U^2 - 43.3U + 18.6) \times 0.3 + (-0.1M + 5.8) \times 0.3 + (0.001L^2 - 0.1L + 4.4) \times 0.4$

   d. TSP generation of Latosol soil from Padang city

   $E_{TSP.Pad} = (260.3U^2 - 394.1U + 178.5) \times 0.2 + (-0.006M^2 - 1.0M + 48.4) \times 0.4 + (-0.01L^2 + 0.2L + 28.6) \times 0.4$

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