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Prediction and Modelling of Total Suspended Particulate Generation on Ultisol and Andisol Soil

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ABSTRACT

Total suspended particulates (TSP) are small airborne particles such as dust, fume and smoke with diameters less than 100 micrometers. They are emitted from various sources including power stations, construction activities, incineration and vehicles. Research objective were to analyze the correlation between Total Suspended Particulate (TSP) and wind speed, soil moisture content, and the percentage of land cover on Ultisol and Andisol then modelling of TSP generation prediction. TSP samples were collected by the gravimetric method (SNI19-7119.3-2005). TSP generation correlated positively with wind speed and correlated negatively with soil moisture content and the percentage of land cover. Effect of wind speed on the TSP generation Ultisol was 86.2% and Andisol was 46.1%. Effect of soil moisture content on the TSP generation Ultisol was 64.8 % and Andisol was 71.5%. Effect of the land cover percentage on TSP generation Ultisol was 84.4% and Andisol was 92.9%. The TSP generation model for Ultisol was $TSP = 22.36\ u^{4.10} - (-243.26)\ \Theta^{-0.46}$, with $R^2 = 0.9692$. The TSP generation model for Andisol was $TSP = 57.54\ u^{6.08} - (1.42*10^{9})\ \Theta^{-4.63}$, with $R^2 = 0.9578$.

Keywords: *Andisol, soil moisture content, Total Suspended Particulate, Ultisol, wind speed,*

1. INTRODUCTION

Total suspended particulate (TSP) is a very important component of the ambient air quality. This parameter has to be measured in accordance with Government Regulation no. 41 of 1999 pertaining on Air Pollution Control. TSP concentration that exceeds the quality standard will cause serious and diverse negative effects, both for health, economic, and environmental aspects (Setiawan 1992; Kellogg and Griffin 2006; Laurent *et al*. 2006; McTainsh and Strong 2007; Feng *et al.* 2008; Zhou 2010). Particulate matter can lead the changes of solar radiation in the atmosphere which absorbed by the earth's surface (Kaufman *et al*. 2002; Mahankale 2009).

Increasing concentration of total suspended particulate (TSP) in the ambient air is caused by wide range of human activities, such as mining, transportation, land clearance, construction of residential areas, land conversion, land cultivation, deforestation, etc. An emission of dust (particulate matter) is highly depending on wind speed, surface roughness, and atmospheric stability (Gillette and Passi 1988). The equation used to estimate the generation of suspended particles (TSP) in the ambient air in Indonesia is an empirical equation of Niemeier *et al.* (2000) derived from California (USA) that is not in accordance with the conditions in Indonesia. The purpose of this study were to measure the concentration of total suspended particulate (TSP) and to analyze its correlations in the ambient air with the variation of wind speed, soil moisture content, and the percentage of land cover in the laboratory scale. The other purpose was to develop prediction model of total suspended particulate (TSP) generation based on wind speed and soil moisture content.

2. RESEARCH METHOD

2.1 Time and Place

This study was carried out in July 2013 to March 2014. Series of the measurements were carried out in Laboratory of Environmental Engineering, Department of Civil and Environmental Engineering with Ultisol soil sample taken from Bogor Region and Andisol taken from Kuningan Region, Indonesia.

2.2 Materials and Instruments

The materials and instruments used during the laboratory experiments were a High Volume Air Sampler (HVAS) [Staplex-USA TFIA-2], filter paper/A 1.6 µm [Whatmann #1820-110], tunnel [7.6 m length; 0.76 m width; 2.4 m height], air velocity meter [VELOCICALC 8357 - TSI], barometer [OSK 721], digital moisture tester [OGA Model TA-5], blower [Hercules; Ø = 24"; 220 V; 50 Hz: 170 W], timer, oven [Fisher], analytical balance [Mettler Toledo], Minitab 14 Portable.

2.3 Measurement of TSP Generation in the Laboratory

The measurement of total suspended particulate was conducted in a laboratory scale tunnel where the land surface was covered by Ultisol and changed by Andisol with 3 cm depth. The tunnel dimension used for measuring the concentration of TSP in the laboratory was 7.6 m length, 0.76 m width and 2.4 m height (Figure 1). TSP was sampled actively by sucking the air above soil sample on a certain volume through a fibreglass filter/paper, using High Volume Air Sampler equipment (HVAS) with an average flow rate of 1.13-1.70 m^3/min (SNI19-7119.3-2005). Wind with 0.5-1.7 m/s speed was mechanically generated by a blower 1.5

m above soil surface in the tunnel. Method of measuring the TSP generation is shown in Figure2.

Fig 1: Tunnel for the measurement of TSP

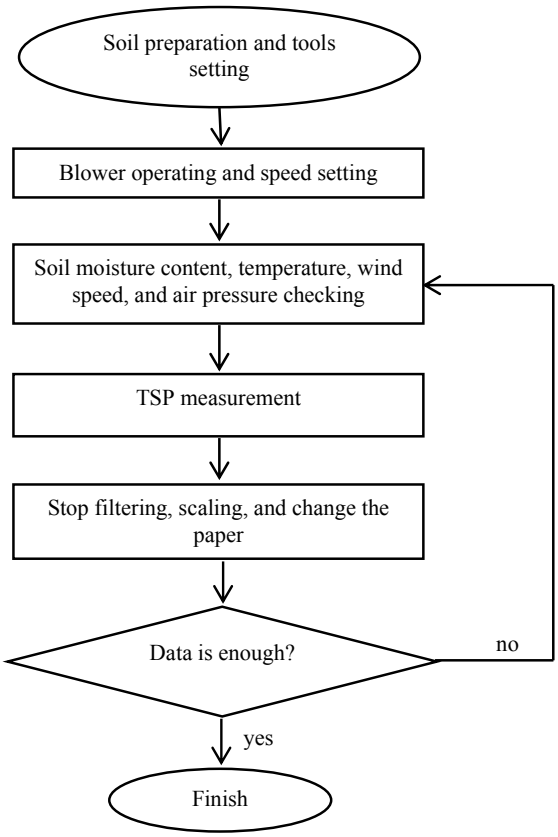

Fig 2: Method of measuring the TSP concentration

2.4 Data Analysis

Referring to Sugiyono (2011), the data analysis techniques used in this study was Pearson Correlation Product Moment. Data analysis was performed with the aid of a personal computer using data processing program Minitab.

Regression analysis is one of very popular statistical tool used in processing statistics data. Regression analysis is used to determine the relationship of one or more dependent variable and one or more independent variables. Polynomial regression is a linear regression model which formed by summing the effect of each predictor variable (X) and degreed until the k^{th} order. TSP concentration value prediction modelling use polynomial regression models with solver program on Microsoft office excel. TSP constructing equation is $TSP = a\ u^{b} - c\ \Theta^{d}$, where u is wind speed and Θ is soil moisture content.

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis of TSP Generation on Ultisol

The result of analysis on Ultisol indicated that there were positive correlation between TSP generation and wind speed. Linear correlation between TSP generation and wind speed on Ultisol has R-Sq value 86.2% for wind speed 0.5-1.6 m/sec (Figure 3). The graph describes that the generation of TSP on Ultisol was influenced by the local wind speed at 86.2%.

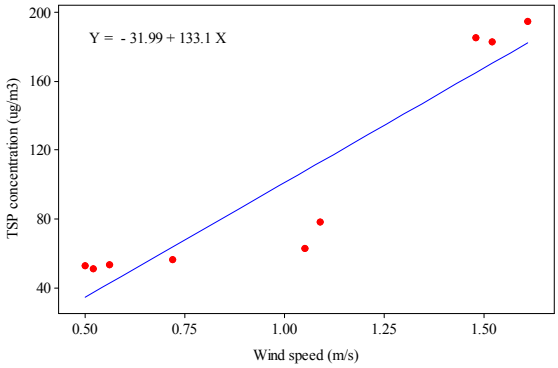

Fig 3: Correlation between TSP and wind speed on Ultisol

The linear correlation between TSP generation and soil moisture content of the Ultisol has R-Sq value 64.8% with soil moisture content of 25.0-35.4%. This explained that the generation of TSP from Ultisol was influenced by the soil moisture content as much as 64.8%. Correlation between TSP generation and soil moisture content on Ultisol is presented in Figure 4.

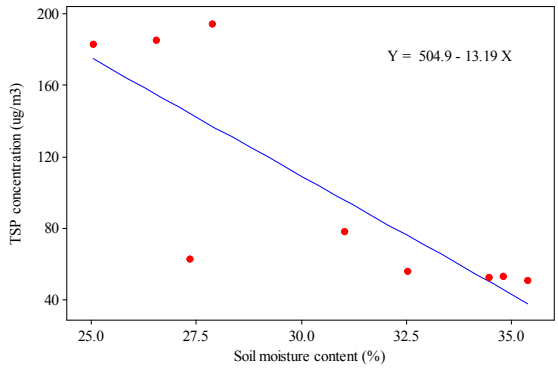

Fig 4: Correlation between TSP and soil moisture content on Ultisol

The correlation between TSP generation and wind speed as well as soil moisture content was suspected to be affected by soil texture. Texture is a very important

characteristic because it affects the properties of the chemical, physical, and biological properties of soil. Soil can be divided into two classes, namely rough and smooth soil textured. These classes can be classified into several types such as clay, sand, and dust. Based on the results of soil analysis at Soil Laboratory Bogor Agricultural University, Ultisol soil sample contains 27.48% sand, 23.34% dust, and 49.18% clay. Refer to triangle soil texture diagram (USDA 1966), the value was categorized into clay which has high weight, shaping like the ball, and attached each other.

The land cover is important factors that affect the generation of TSP besides wind speed and soil moisture content. It was applied to the tunnel by 10%, 20%, 30%, and 40%. The increasing of land cover proven effective to reduce dust (particulate matter) generated from the soil surface (Shang, et al. 2012). The correlation between TSP generation and land cover on laboratory measurements showed a correlation with the P-value was less than α (0.05). The results of measurements on Ultisol showed that land cover was negatively correlated with TSP generation and has the effect of 84.4 % (R-Sq = 84.4 %) (Figure 5).

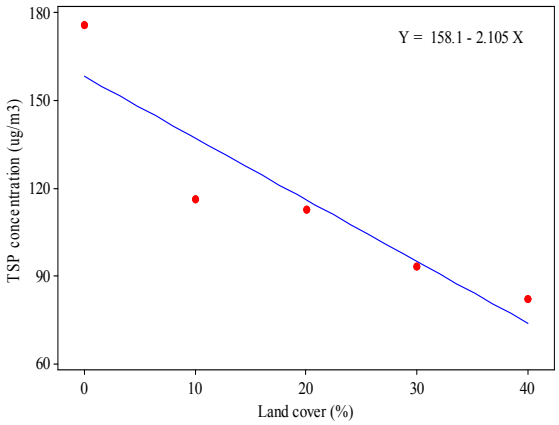

Fig 5: Correlation between TSP generation and land cover on Ultisol

3.2 Correlation Analysis of TSP Generation on Andisol

The result of the correlation analysis showed that there was a linear relationship between TSP generation of Andisol and wind speed (Figure 6). Effect of wind speed at 0.8-1.7 m/s for TSP generation in the laboratory measurement was 46.1%.

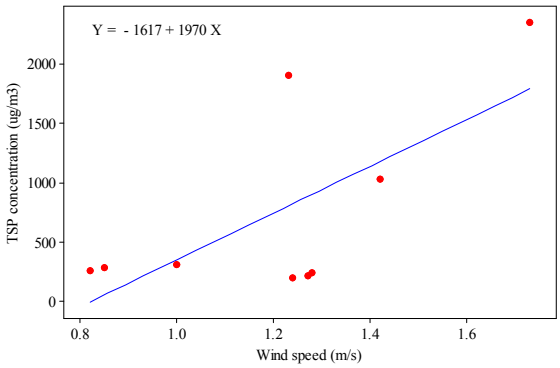

Fig 6: Correlation between TSP generation and wind speed on Andisol

Andisol is black soil (epipedon mollik or umbrik), has kambik horizon, bulk density less than 0.85 g/cm^3, and contain many amorphous materials. Based on the laboratory testing, Andisol samples contain 43.02 % sand, 33.72 % dust, and 23.26 % clay. This proportion is categorized into the clay class based on the USDA category, where the soil is not rough and smooth, firm ball forming, slightly rolled with shiny surface and attached. The physical properties of Andisol is high water binding power, very loose structure, high degree of resilience so easily processed, and a high permeability (Soil Survey Staff 1990).

The results of the correlation analysis also showed a linear relationship between soil moisture content and TSP generation on Andisol. Soil moisture content influence 71.5% (R-Sq = 71.5%) to the TSP generation on Andisol. Measurement of TSP generation on Andisol conducted at the soil moisture content levels of 19.0-35.4%. The resulting linear regression graph is shown in Figure 7. The influence of soil moisture content on Andisol's TSP generation was higher than Ultisol's TSP generation.

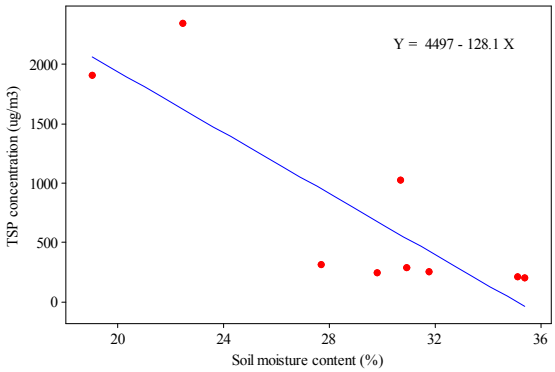

Fig 7: Correlation between TSP generation and soil moisture content on Andisol

Linear relationship is also shown by the results of correlation analysis between the TSP generation and land cover on Andisol (0-40%). Referring to Niu, et al. (2004), vegetation cover will influence the wind speed threshold in dust generated from soil erosion. Areas

which have low rainfall and low vegetation coverage will generates high dust. Land cover types such as agriculture or grassland will obtained dust generation about 0-50%. However, it is influenced by the spatial and temporal aspects of the dust emission as well as the availability of land and the local wind data (Yoshioka, et al. 2005). The influence of land cover on TSP generation on Andisol was 92.9 % (R-Sq = 92.9%). Negative correlation of land cover and TSP generation on Andisol is presented in Figure 8.

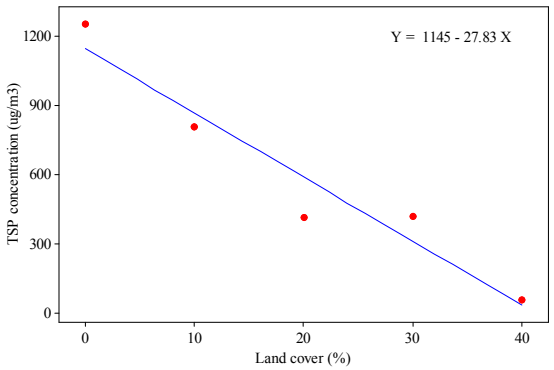

Fig 8: Correlation between TSP generation and land cover on Andisol

3.3 Total Suspended Particulate (TSP) Concentration Estimation

The TSP equation is TSP = a u^{b} – c Θ^{d}, where u is wind speed and Θ is soil moisture content. Based on result from the laboratory measurement, the equation of TSP generation for Ultisol is:

$$TSP = 22.36\ u^{4.10} - (-243.26)\ \Theta^{-0.46}.$$

R^2 obtained was 0.9692, which closed to 1, meaning that the regression line model is accurate. The equation was valid when the conditions of wind speed at 0.5-1.6 m/s. The Ultisol soil moisture content was 25.0-35.4 %, with certain soil texture (27.48% sand, 23.34% dust, and 49.18 % clay). Graph model of the generated TSP on Ultisol is shown in Figure 9.

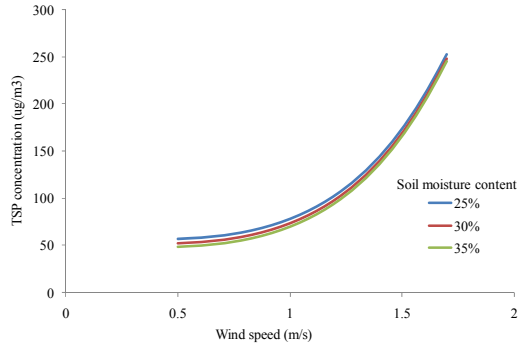

Fig 9: Graph model of TSP generation on Ultisol

The equations model of TSP generation on Andisol obtained from result of Laboratory measurement was:

$$TSP = 57.54\ u^{6.08} - (1.42*10^{9})\ \Theta^{-4.63}.$$

Accuracy (R^2) of this equation was 0.9578. The equation is valid when the conditions of wind speed is 0.8-1.7 m/s, soil water content is 19.0-35.4%, and soil texture include 43.02% sand, 33.72% dust, and 23.26% clay. Graph model of the generated TSP on Andisol is plotted in Figure 10.

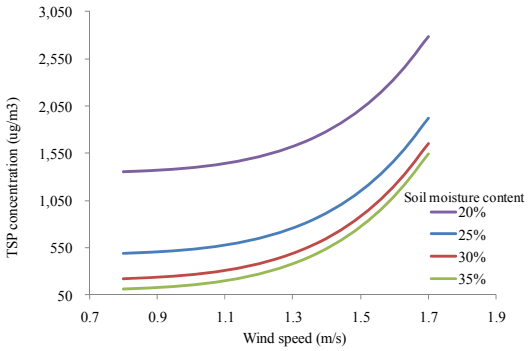

Fig 10: Graph model of TSP generation on Andisol

4. CONCLUSION

The conclusions of this research are:

1. Generated Total Suspended Particulate (TSP) has a positive correlation with the wind speed, negatively correlated with soil moisture content and percentage of land cover
2. Results of measurements in the laboratory showed that :
   a. The influence of wind speed on TSP generation Ultisol was 86.2% and Andisol was 46.1%
   b. The influence of soil moisture content on TSP generation Ultisol was 64.8% and Andisol was 71.5%.
   c. The influence of land cover percentage on Ultisol TSP generation was 84.4 % and Andisol was 92.9%.
3. The accuracy of Ultisol TSP generation model was 0.9692 whereas for Andisol TSP was 0.9578.

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