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Effects of the green space proportion with cumulative concentration of particulate matter 10 (PM10) in Surabaya- Indonesia

Muzayanah*[1], Ariffin[2], Sudarto[3], Yanuwiadi B.[4]

[1]Doctoral program natural resources management and environment, Agriculture sciences, Brawijaya University, Malang, Indonesia
[2,3] Faculty of agriculture, Brawijaya, University, Malang, Indonesia
[4]Department of biology, Faculty of mathematics and natural science, Brawijaya, University, Malang, Indonesia

Abstract: The concentration of particulate matter 10 (PM10) in ambient air Surabaya Indonesia sometimes exceed ambient air quality standard. Particulate Matter 10 (PM10) in ambient air can be reduced by green space area. The cumulative of PM10 concentration for 24 hours in ambient air (K-PM10) is used as an indicator of the reduction of PM10 by green space. There is a correlation between the fraction of green space area with a value reduction of KPM10. Increased level of green space fraction resulting effect of decreasing the level of K-PM10. The increase in the fraction of green space caused a decline in the value of K-PM 10. The decline in K-PM10 level is indicative of an increase of reduction of PM10 concentration in ambient air. Determination of the fraction of green space as a solution to the reduction of the PM10 concentration in ambient air.

Introduction

The results of the research that has been done in several cities shows that PM10 concentration in some cities tend to be high. The concentration of PM10 in some cities enter the category of polluted air according to WHO[1-8]. The concentration of PM 10 in the city of Surabaya as the second largest city in Indonesia sometimes exceed the quality standard of clean air, especially during the dry season[22].

Sources PM10 can come from transportation activities, resuspended dust, industrial activity and household [4,8-11]. One of the environmental services of a plant is as a filter dust or PM10[12]. Particulates can be absorbed by the part of the plant, such as leaves and stems of plants. The process of absorption of particulates on the surface of the plant occurs via the process of diffusion Brown, impaction, interception and sedimentation[13-15]. Plant functions as a filter dust causing particulates PM10 in ambient air or reduced. In other words, there was a reduction in the PM10 concentration in ambient air by plants. Plants in urban synonymous with the city park or green space. So that the particles or PM10 be reduced to the city park or green space[16-20].

The value of the reduction of PM10 in ambient air by green space measured by the cumulative value of PM10 concentration in ambient air for 24 hours[21-22]. The cumulative value for PM10 concentration in ambient air for 24 hours (K_PM10) is obtained from the time series data of ambient air PM10 concentrations during the 24 hour period. Taken over a period of 24 hours because 24 hours is the shortest meteorological cycles and cycles of human activity. If the value of K_PM0 is negative (-) means a greater reduction of emissions of PM10 sources. In other words, the green space in the area is sufficient. Conversely, if the value KPM10 positive sign (+), meaning the reduction of PM10 is smaller than the source of PM10 emissions. In other words, the green space in the area is inadequate.

Applications reduction value calculation been used to analyze the PM10 concentration of the research results by Speak[19] and Gummeneni[4]. Daily PM10 concentration measurements were performed Speak[19] in 3 locations in Manchester-UK used as study materials. PM10 concentration curve is analyzed to obtain the value KPM10 ambient air during the period of July 8 to August 3, 2011 (27 days). From the area between curve calculations rate of change of concentration [$\Delta C/\Delta t$] line [ΔC / $\Delta t = 0$], the value KPM10 for 27 days (July 8 to August 3, 2011) as follows:

a. K_PM10 (*Roof 1)* = 61.89 □g/m^3 ambient air,
b. K_PM10 (*Roof 2)* = 13,31 □g/m^3 ambient air,
c. K_PM10 (*Picadily Garden)* = 9,05 □g/m^3 ambient air.

The calculations show that all locations have value KPM10 positive (+), meaning that in all locations by an additional concentration of PM10. Value KPM10 positive (+) means that during the observation period did not happen reduction of PM10. Value KPM10 smallest occurred in Picadiliy Garden because the proportion of green space larger than other locations. While the greatest value is in the roof KPM10 1 located near the freeway. This case study shows that the value KPM10 influenced by the proportion of green space and a source of emissions.

KPM 10 calculation method was also applied to the results of research in Punjagutta, India by Gummeneni[4]. PM10 concentration data during weekdays and holidays analyzed to obtain the value K_PM10 for 24 hours. From the calculation of spacious shaded area between the curve of the rate of change of concentration [$\Delta C/\Delta t$] line [$\Delta C/\Delta t = 0$] K_PM10 values obtained for 24 hours as follows:

a. K_PM10 holidays = - 153.7 □g/m^3 ambient air,
b. K_PM10 weekdays = 57,9 □g/m^3 ambient air.

The calculations show that on holidays, the value K_PM10 is negative (-), which means there is a reduction of PM10 ambient air at 153.7 □g/m^3. On weekdays, the value K_PM10 is positive (+), which means that the reduction of PM10 by green space is lower than PM10 emissions. The ability to reduce PM10 with green space in the area can not exceed emissions of PM10[22].

Experimentals

Observations conducted in Surabaya, Indonesia. The location of observation is an area of ambient air quality monitoring stations belonging to the Surabaya municipal administration (Figure 1).

Figure 1. Location of monitoring station in Surabaya

Materials used are:

a. Satellite image of the area around the air quality monitoring stations in 2002-2014 ,
b. PM10 concentration data in 2002 to 2014,
c. wind direction and wind speed data in 2002-2014,

The unit of analysis using the box model method, where the extent of the unit of analysis depends on wind direction and wind speed[23]. The unit of analysis changes every day, depending on wind direction and wind speed. Determining the unit of analysis is presented in Figure 2. Area unit of analysis is

$A = (L^2)$ ……………..(1)

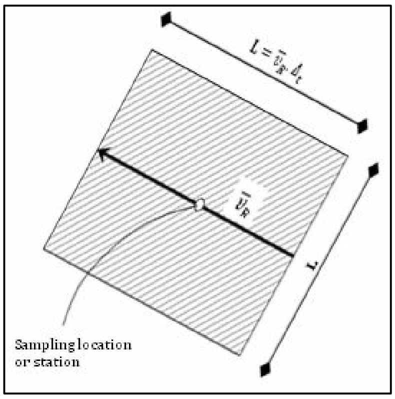

Figure 2. Determination of unit analysis

The wind is a vector quantity that has a value and direction. Average wind direction is the sum of wind vector divided by the number of wind data[24], then:

$$\overline{v}_R = \frac{\overline{v}_{t1} + \overline{v}_{t2} + \overline{v}_{t3} + \cdots + \overline{v}_{tn}}{n} \quad ....…...................(2)$$

$$\overline{v}_{\square} = \overline{v}_x + \overline{v}_y \quad ……………….………………… (3)$$

After knowing the extent of the image analysis unit, do delineation and calculation of the proportion of green space and not a green space in the image.

Data wind direction, wind speed and PM10 concentrations obtained from the recording of six air quality monitoring station in Surabaya. Figure 3 presents the air quality monitoring stations. Data PM10, wind speed and wind direction are used, adjusted to the time of shooting the image.

Figure 3. Monitoring station of air quality

Method of calculating the reduction value of PM10 (K_PM10)

The cumulative value of PM10 concentration in ambient air for 24 hours (K_PM10) is

$$K\_PM10 = \frac{\Delta C}{\Delta t} \quad \text{...(4)}$$

ΔC is the change in the concentration of PM10 during the one period (Δt). The cumulative value of the PM10 concentration during 24 hours (K_PM10) can be expressed by $\int \Delta C/\Delta t$. The cumulative value of PM10 concentration during the period was the result of the integration of the rate curve PM10 concentration during one period. Cumulative PM10 concentrations equal to the area between the curves $\Delta C/\Delta t$ with a line ($\Delta C/\Delta t = 0$). The area between the curves ($=\Delta C/\Delta t$) with line ($\Delta C/\Delta t$) = 0 can be calculated by numerical integration. One method is a numerical integration of the trapezoid many parts[25]. The area between the curves $\Delta C/\Delta t$ with a line ($\Delta C/\Delta t = 0$) or K_PM10 can be calculated by the following formula

$$K\_PM10 = \Delta c\,\frac{f(t0) + f(t1)}{2} + \Delta c\,\frac{f(t1) + f(t2)}{2} + \cdots + \Delta c\,\frac{f(tn-1) + f(n)}{2} \quad \text{...(5)}$$

$$K\_PM10 = \frac{\Delta c}{2}\left[f(t0) + f(tn) + 2\sum_{i=1}^{n-1} f(ci)\right] \quad \text{............................ (6)}$$

Value K_PM10 have negative sign (-) indicates that the PM10 reduction is greater than PM10 emissions. Value K_PM10 have positive sign (+) indicates that the PM10 reduction is smaller than PM10 emissions. K_PM10 have value equal to zero (0) means the process of PM10 reduction and PM10 emissions in balance.

Result and Discusion

Monitoring station 1 (Gayungan) located near the freeway Surabaya Gempol that have high traffic activity. These stations represent conditions in residential areas and transportation. Monitoring station 2 (Gebang) located in the middle of residential and office. Monitoring station 3 represents the state of downtown Surabaya. Monitoring station 4 (Sukomanunggal) represents a dense residential area. Monitoring station 5 (Wonorejo) represents green space and residential area . Monitoring station 6 (Kebonsari) represents the transport area and residential area. Results delineation of green space on the image and value of K_PM10 presented in Table 1.

Table 1. Results delineation of green space in the image and reduction value of PM10 concentration in ambient air for 24 hours (K_PM10)

Station	Location	Years	% Green space (G)			K_PM10 ($\mu g/m^3$)		
			Min	Max	Average	Min	Max	Average
1	Gayungan	2009 - 2012	45.38	100.00	63.24	-24.40	109.70	24.09
2	Gebang	2002 - 2012	28.49	69.23	42.87	-195.70	292.58	61.29
3	Taman Prest	2004 - 2013	55.30	92.98	65.24	-111.40	105.58	24.46
4	Sukomanung	2013	33.52	65.73	53.33	-9.60	43.90	6.94
5	Wonorejo	2013 - 2014	35.69	79.46	68.15	-106.10	106.34	20.93
6	Kebonsari	2014	26.47	33.60	28.83	-13.17	263.93	61.40

Graph of the relationship between the proportion of green space and the reduction value of PM10 concentration in ambient air for 24 hours (K_PM10) served on Figure 4.

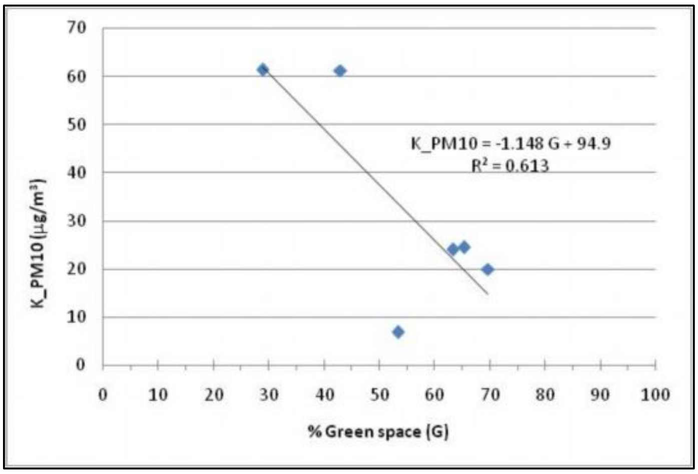

Figure 4. Relations between the proportion of green space and a value reduction K_PM10

Figure 4 shows that green spaces negatively affect the value of PM10 reduction in ambient air. The greater of green space proportion, then the reduction value PM10 (K_PM10) will be smaller. These results support previous research that green space can reduce the PM10 concentration in ambient air. Green spaces negatively affect the value K_PM10 support research geography and forestry, which states that the plant has the ability to reduce PM10 from the ambient air[16-20]. The greater the proportion of tree canopy cover, there is a tendency for PM10 ambient air is getting smaller.

The wind helps PM10 move horizontally and vertically. The movement of PM10 due to wind caused PM10 adsorbed on plant parts such as leaves and stems of plants. Reduction of PM10 in plants due to the Brown diffusion process, impaction, interception and PM10 sedimentation in plants[13-14]. The reduction is referred to as direct reduction . PM10 reduction can occur indirectly. Indirect reduction occurs because the plants are able to change the local meteorological conditions, such as humidity increases. High humidity indicates the moisture content is high ambient air. Water vapor can bind PM10 thereby reducing PM10 is dispersed into the ambient air. Attachment of PM10 in ambient air in the plant can be seen from the PM10 mass adsorbed on the part of the plant[15,19,26-28]. The more plants causing more and more of PM10 in ambient air are adsorbed on the plant. The more PM10 absorbed cause lower concentrations of PM10 ambient air. This causes the rate for 24-hour PM10 concentration or value K_PM10 getting smaller. K_PM10 value is smaller , indicating that the reduction of PM10 ambient air occurs, the greater .

Conclusion

Green space has the ability to reduce the PM10 concentration in ambient air. The greater proportion of green space make the value of the PM10 reduction in ambient air will be smaller. The rate of reduction of PM10 in ambient air can be measured by the cumulative concentrations of PM10 ambient air for 24 hours (K_PM10). The amount of the required proportion of green space in the area can be determined from the value K_PM10.

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