The Effect of Green Open Space Proportion on Air Ambient PM10 Reduction of Surabaya City

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***Abstract*—This paper presents the information of effect green open space on to ambient air PM10 reduction of Surabaya city. The reduction value used the PM10 concentration cumulative indicator for 1 time period (K_{PM10}). 1 time period is 24 hours. Time series data were taken in 2002-2014. The PM10 reduction value and green open space percentage were used.**

Keywords— propose, RTH, reduce value, PM10

I. INTRODUCTION

The majority of suspended particles in the ambient air are PM10 (Particulate Matter 10). Another name for PM10 is Total Suspended Particulate (TSP). PM10 has a diameter of less than 10 µm, drifts in the air and does not easily settle [1][2][3]. PM10 is one of the few ambient air pollutants [1][3][2].

The concentration of PM10 in some cities in the world has exceeded the healthy threshold set by the WHO, which is 80 µg / m^3. In fact, in some cities there are already exceeding the standard set by USEPA, that is 150 µg / m3. [4][5][6][7][8][9]. High PM10 concentrations negatively affect the ecosystems, blocking outlook and disrupting human health. [1][2][10][11].

The concentration of ambient air PM10 comes from transport activities, resuspended dust, industrial activity and households [12][6][13]. The ambient air PM10 concentration of an area is significant with activity in the area. Activity in an area is identical to land cover.

Vegetation in urban open green spaces able to reduce PM10 [14][15][16][17]. The PM10 reduction can be seen from the mass of PM10 attached to the plant part. The more plants, the more ambient air PM10 absorbed [18][16][19]. Evident from PM10 concentration outside green open space park was higher than PM10 concentration inside green open space park [20]. Areas that have a larger proportion of green open space, have lower PM10 concentrations [17].

The ambient air PM10 application can be seen from the concentration rate during 1 period. Period of PM10 concentration rate was collected during 24 hours. The period was determined because of the shortest (day-night) meteorological cycle and the cycle of human activity (daytime activities and resting nights) [21].

II. RESEARCH METHODS

A. Criteria of reduction value

The cumulative value of ambient air PM10 concentration for one period (= K_PM_{10}) can be used as an indicator of the PM10 reduction process. The reduction value of K_{PM10} is calculated from the change of PM10 concentration (Δm) of each ambient air volume (ΔV) for 1 time period (Δt). When the concentration of PM10 is the ratio between PM10 concentration per ambient air volume, then PM10 concentration rate of each ambient air volume is the change of PM10 (Δm) concentration of each ambient air volume (ΔV) for 1 period (Δt).

$$K\_{PM10} = d(m/V)/dt = dC/dt \quad (1)$$

The positive K_{PM10} reduction value (+) in the case of PM10 concentration increase at 1 period (Δt). The value of KPM10 is positive (+), meaning that PM10 reduction is less than PM10 emission. Negative K_{PM10} value (-) in the case of PM10 concentration decrease at 1 period (Δt). K_{PM10} value is negative (-), meaning that PM10 reduction is greater than PM10 emission. The value of K_{PM10} is equal to zero (0) meaning that both reduction processes and ambient air PM10 emission are in balance. By calculating the value of K_{PM10} as an indicator of the magnitude of PM10 reduction of ambient air by green open space, it can be seen the adequacy of green open space in the area [21].

B. Location and Time of Study

The study was conducted in Surabaya which has PM10 concentration problem above WHO healthy air criteria. Surabaya city since 2002-2014 has 8 (eight) ambient air quality monitoring stations. Of the 8 monitoring stations, there is 2 air quality monitoring stations that can not be obtained because the land cover data from google earth is not available. The PM10 time series data was taken from 2002-2014. The research was done by random sampling method. The sample used was 60.

TABLE I. LOCATION OF WATER QUALITY MONITORING STATION IN SURABAYA

Station location code	Location of the monitoring station	Operation year	Coordinate x (m)	Coordinate y (m)
1	Perak*	2002 - 2004	691401	9201132
2	Sukomanunggal 1*	2002 - 2004	687147	9196056
3	Gayungan	2002 - 2012	689498	9188463
4	Gebang	2002 - 2012	696983	9193990
5	Taman Prestasi	2002 - 2013	692390	9196946
6	Sukomanunggal 2	From 2013	689047	9196994
7	Wonorejo	From 2013	697520	9191373
8	Kebonsari	From 2013	689177	9189578

The location of the monitoring station is presented in Fig 1. The yellow point is the sign of a monitoring station whose data can not be taken. The red point is a monitoring station whose data can be taken data.

Fig 2 shows air quality monitoring stations owned by the Surabaya city government. Fig 3shows the sensor device at the air quality monitoring station

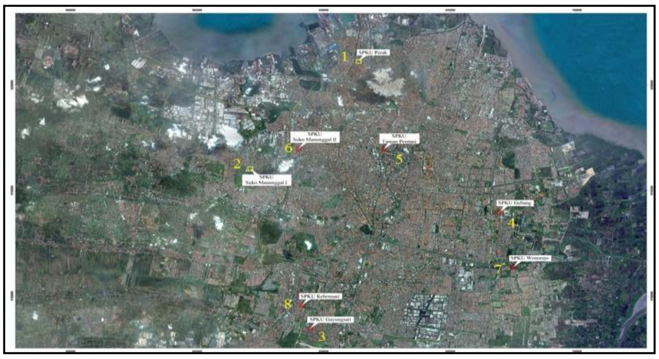

Fig 1. Monitoring station location in Surabaya

Fig 2. Monitoring Station in Surabaya

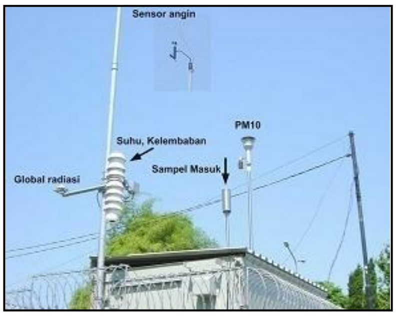

Fig 3. Sensor device of the air quality monitoring station (Surabaya city government, 2010)

C. Tools and Materials

Tools and materials needed are:

a. Image captured from Google earth,
b. PM10 concentration data, wind direction, and velocity at 6 monitoring stations under image represented conditions.
c. Coordinate and elevation data, obtained from GPS measurements in the field.

The research was conducted by a random sampling method. The sample used is 60.

D. Determination of analysis unit

Analysis unit changes every day, depending on wind direction and velocity. Determination of analysis unit using box modelling method [21].

E. Observation of analysis unit

Observation of unit analysis was done by delineation of green open space and nongreen area. After the delineation is completed, a percentage of each delineation is calculated.

III. RESULTS AND DISCUSSION

A. The concentration of average PM10

Effect of green open space proportion on PM10 average concentration is presented in Fig 4.

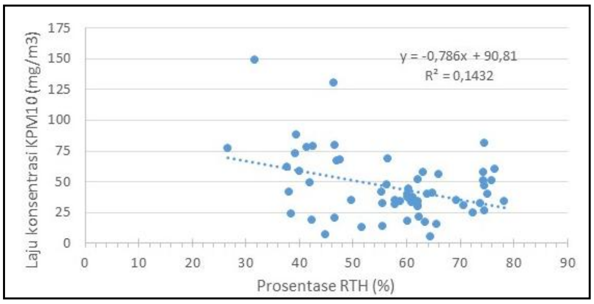

Fig 4. Relationship of green open space proportion with a concentration of ambient air PM10

Figure 4 shows that the proportion of green open space had a negative effect on the average PM10 concentration of ambient air. The greater the proportion of green open space will reduce the average PM10 concentration of ambient air. This indicates that the vegetation on the green open space is able to reduce or absorb ambient air PM10.

The linear model of the effect of green open space proportion on PM10 average concentration is stated as follows:

$$Y = -0{,}786X + 90{,}81 \quad (2)$$

Equation (2) shows that the proportion of green space has a negative effect directly on the average PM10 concentration of 0.786. every increase in the percentage of green open space will decrease the concentration of PM10 air ambient by 0,786.

Anova analysis with SPSS resulted in sig (0.003) < α (0.05). This shows that the linear model between the proportion of green open space with the average PM10 concentration of ambient air is significant.

The ability of vegetation in green open space to absorb PM10 through 4 processes, namely Brown diffusion, collision, interception and sedimentation [1][22]. Particulate size <1 μm: precipitated by Brown diffusion. Particulate deposited by Brown diffusion will be firmly attached to the plant surface, such as in leaves and stems. This particulate cannot be removed by the wind.

The collision process occurs when a mass stream of air containing particulates at a time approaches obstructions, such as a plant, its flow will be deflected. Time is deflected, airflow is divided. The particulates present in the air mass tend to continue through the obstructions but due to the reduced power it stops and falls in the area around the obstructions. Precipitation through the collision process occurs in large particulates.

Interception process occurs when the air mass containing the particulate at a time approaches the obstructions, its flow is not deflected but touches the obstructions surface. Hairy plant leaves capture particulate matter through interception

Sedimentation process occurs because of the influence of gravity. This process occurs mainly on large particulates. This is due to the large particulate tends to be heavier, thus speeding up the deposition process [22].

Leaf surface morphology, twigs, and stems of plants become the dominant factor in particulate adsorption. [23] Needle leaf plants had higher particulate absorbing ability than smooth-leaved plants [24]. Feathery branches absorb more particulates than the slippery branches. Rough-skinned trees absorb more particulates than slippery trees [25].

The coefficient of determination (R^2) in equation (2) is 0.1432. Thus the average PM10 concentration of ambient air 14.32% is influenced by the proportion of green open space. A total of 85.68 are influenced by other variables not studied, such as wind velocity, humidity, temperature, activity in the area and type of plants in green open space.

B. *Reduction of PM10*

The PM10 concentration data of an area has not provided information on the PM10 reduction process that occurred during the observation period. So it can not be known which area has the biggest PM10 reduction value. The ambient air PM10 reduction value in an area (K_PM10) can be analyzed with PM10 concentration cumulative value with Box Model theory [26].

The effect of green open space proportion ambient air PM10 reduction value is presented in Fig 5.

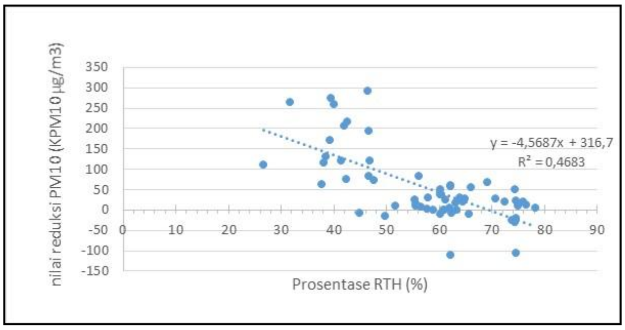

Fig 5. The relationship between green open space proportion with PM10 ($K_{\_PM10}$) reduction value

Fig 5 shows that the proportion of green open space has a negative effect on PM10 reduction (K_PM10). The greater the proportion of green open space will increase the PM10 concentration reduction within a 24-hour period. This indicates that the vegetation on the green open space is able to reduce or absorb ambient air PM10.

The regression model of the effect of green open space proportion on the average concentration of PM10 is expressed as follows:

$$Y = -4{,}569X + 316{,}7 \qquad (3)$$

Equation (3) shows that green open space (RTH) as ambient air PM10 reducing agent has a negative effect directly on K_PM10 of 4.569. every increase in the percentage of green open space will decrease the K_{PM10} value of 4.569.

Anova analysis with SPSS resulted in sig (0.003) < α (0.05). This shows that the linear model between the proportion of green open space with PM10 reduction value is significant

All parts of the plant have environmental services. Plants have environmental services as absorbers of carbon dioxide, oxygen producers, dust absorbers (particulates), noise absorbers, windbreakers and groundwater storage [27]. One of the few environmental services of plants is as a dust or particulate filter. Particulate can be filtered by plants because particulates can be absorbed in parts of plants, such as leaves and stems of plants [25][24]. The function of the plant as a dust filter causes the particulate or PM10 in ambient air to decrease.

Green open space had a negative effect on K_{PM10} supporting research from the field of Geography and Forestry which determined that the plant is able to reduce PM10 from the ambient air [14][15][16][17]. The greater the percentage of tree canopy cover, the greater tendency of green open space capability to absorb PM10. The greater ability to absorb of ambient air PM10 causes ambient air PM10 reduction is also increasing [21][28].

Plants in the green open space have the ability to neutralize concentrations of pollutants to the critical point that cause physical damage. The critical points of each plant on particulate pollutants are varied. Some tree species have special mechanisms to avoid specific damage from particles. This includes changes in the timing of the appearance of leaf buds or fall, and the ability to produce new leaves when damaged [25]. For this reason and other physiological mechanisms, some trees can grow better under pollution.

The ability of plants to reduce air pollution is generally influenced by several factors [24]:

(1) Specific plant species are related to the following properties:

(a) Leaf surface roughness.

The rougher the leaf surface, the ability to precipitate and accumulate lead will be greater than the slippery and waxy surface of the leaf.

(b) Physiological Characteristics:

Transpiration rate; stomata diffusion resistance, canopy, and mesophyll; and absorption of air pollution substances; mechanism of enzyme activity during active oxygen detoxification process.

(c) Leaf lifetime

Leaves that have a longer lifespan have larger periods of time in accumulating pollutants.

(d) Structure of branches and stems

The leathery branches with the horizontal or V-shaped branching upwards will more effectively absorb and intercept dust, lead, and zinc than the branches that hang over the ground. Similarly, bark and hairy stalks are more effective than those with slick waxy skin, because lead particles are easier to wash rainwater or are easily blown off.

(e) Size, shape and wetness and surface texture of leaves and particles.

(f) Size of stomata.

Particles that have a smaller size than stomata gap, then can be absorbed by the leaves on its surface, can also be absorbed into the leaf through the hole stomata. Stomata length size is about 10μm and its width is about 2-7 μm.

(2) Crop Design and Landscape Architecture

The composition of plants arranged according to their ecological functions can be more effective in reducing air pollutants. This can be done by planting plants that have different properties and capabilities in reducing air pollutants, applying canopy multi-strata patterns and layered mixtures, as well as various types of different leaf sizes and canopy glossiness.

(3) Distribution of Plant Communities: plant communities in various functions and forms that are spread evenly throughout the city are more effective in reducing air pollution.

The coefficient of determination (R^2) in equation (3) is 0.4683. Thus, the ambient air PM10 reduction value of 46.83% is influenced by the proportion of green open space. A total of 53.17 is influenced by other unexamined variables, such as wind velocity, humidity, temperature, activity in the area and type of plant in green open space.

IV. CONCLUSIONS

Green open space is able to decrease the average PM10 concentration of ambient air. every increase in the percentage of green open space will decrease the concentration of PM10 air ambient by 0.786. Green open space has a negative effect on PM10 reduction value with cumulative indicators of PM10 concentration for 24 hours in the ambient air (KPM10). every increase in the percentage of green open space (RTH) will decrease the K_{PM10} value of 4.569.

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