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Research Article

Selecting Plant Types to Control Air Pollution and Developing Software to Plan Green Open Space in the Urban Area

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Abstract

The decrease in air quality becomes one of the development impacts that must be controlled deliberately. Planting trees is crucial for reducing the total number of dust and gas pollutants as it can restrain air pollution through absorption and adsorption. This research aimed at (a) determining the most appropriate types of plants for controlling air pollution and (b) developing software to plan the need for Green Open Space (GOS) in the urban city. The criteria of assessment for measuring the ability of a plant to absorb pollutant gas consisted of: (a) the density level of tree-crown, (b) plant combination, (c) thickness level of leaf, (d) the total number of leaves, and (e) plant distance. Meanwhile, the criteria for assessing the ability of the plant to adsorb dust particles comprised: (a) the roughness of leaf surface structure, (b) leaf width, (c) density level of tree-crown, (d) texture of stem skin surface, and (e) density level of the twig. The results of the research demonstrated that plants of Angsana (*Pterocarpus indicus*), Kihujan (*Samanea saman*), and Acacia (*Acacia auriculiformis*) were very appropriate for absorbing pollutant gas. Meanwhile, the good plants for adsorbing dust particles involved Angsana, Kihujan, Acacia, Tanjung (*Mimusops elengi*), Kersen (*Mutingia calabura*), Ketapang (*Terminalia cattapa*), and red Dadap *(Erythrina crista-galli*) by the level of adsorption ability around 65-75%. The successfully developed software could present suitability between Green Open Space (GOS) calculated manually and the one counted by software.

Keywords: air pollution, green open space, software

1. Introduction

The rapid development has improved people's welfare though it also has brought harmful impacts to the health and environment (Suhariyono, 2002). One of the disadvantages caused by development is the decreasing air quality due to pollution. The increasing activities of industry and traffic belong to the actions of products that contribute to the low quality of air. One of the industrial activities contributing to the reduction of air quality is the cement industry. Pollutants emitted by the cement industry were dominated by silica, having the potential for silicosis disease (Hesaki, 2004) and signified by short breath and dry cough (Nugroho, 2012).

The research concerning the air quality around the cement industrial area had been discussed explicitly by Yuliando (2014), taking the research site at the factory environment of Semen Padang Ltd. His research indicated that several locations obtained a high concentration of TSP, such as the one happening at the residential area of UNAND Block D Gadut by TSP 338.775 μgram/m³ for 24 hours. This concentration was above the quality standard of ambient air 230 μgram/m³ for 24 hours as stated in the Government Regulation of the Republic of Indonesia Number 41 the Year 1999. Accordingly, the cement industry was proven to pollute the ambient air around the factory location.

The other contributor to the reduction of air quality is the improvement of traffic activities. The research of Sara et al. (2020) successfully assessed the contribution of anthropogenic emission in improving the air pollutant. They demonstrated that more than 50% NO_2 pollutant was affected by total vehicles and fuel consumption. Chauhan (2010) revealed that generally, dust or particle coming from traffic and industrial emissions could be hard materials hovering in the air and having toxic properties, thereby endangering human health. Furthermore, Dai et al. (2020) justified that location also determines the phenomenon of air pollution. Their research occurred at the inland area of Hunan China province surrounded by mountains along the three sides. The characteristics of this unique area contributed tremendously to the bad level of pollution.

In addition, Zheng et al. (2020) explained that industry and energy consumption have always become the significant factors exacerbating air pollution. Meanwhile, the innovation of technology belongs to a vital technique for decreasing air pollution. Furthermore, urbanization serves as the other factor worsening air pollution. Karimi and Shokrinezhad (2020) demonstrated that the deaths of babies and kids under five years old correlated to exposure to air pollution. Their research indicated that the values of PM2.5, PM10, CO, NO_2, and SO_2 had positive and significant correlations to the deaths of babies and kids under five years old.

Therefore, to avoid the harmful impacts of air pollution, air quality management is indispensable, such as planning, acting, and monitoring the air quality. To control air pollution, first, the activities of industry and traffic must be aimed at preventing their number and emission-quality through the development of environmentally friendly technology; second, the availability of Green Open Space must be provided. This last stage requires data of GOS needs, including the plant number and type. Next, the stage of implementation and control demands the government regulation regarding the existing GOS (Ram and Pradhan. 2010).

Accordingly, planting trees becomes the solution for controlling the number of dust particles and gas pollutant concentrations. Zampieri et al. (2013) proved that Trichome was a type of plant that could absorb particulate matter (PM) within the size span of 2.5–100 μm. The number of particles being adsorbed per area unit of the leaf differs depending on the sample collection location. The leaves in a relatively unpolluted area indicated the lowest density of particles. At the same time, samples collected in the city center presented the highest number of particles within the aerodynamic sizes of < 2.5 and 2.5–10 μm. Thus, the species of T. granulosa could be employed as a passive biomonitor. Besides, planting T. granulosa in the city area enabled the improvement of air quality by decreasing the dangerous concentrations of PM2.5 and PM10.

Plants serve to absorb as well as to adsorb dust particles and gas pollutants. Accordingly, plants can serve as both the bioindicator for monitoring the air quality and the factory of oxygen needed by humans. Chaudhry and Panwar (2016) affirmed that plants could muffle noises, regulate microclimate, absorb air pollution such as gases (CO, NO_x, SO_x, Hydrocarbon), lead particle (Pb), and adsorb dust particles. Every plant has an unprecedented level of sensitivity in absorbing and accumulating pollutants. Accumulator plant owns the ability for accumulating some aspects in high concentration without triggering toxic effects inside it. Controlling air pollution supported by plants is carried out through two processes, namely absorption, and adsorption. Plant leaves will absorb and adsorb the resulted pollutants (Azzahro *et al.,* 2019). Thus, plants hold influential roles in absorbing air pollutants and clean up the air from certain pollutants. Therefore, plants that will be used as the bioindicator of air pollution must effectively absorb the relatively significant number of air pollutant gases without physiological disturbances.

To ensure that the GOS plan is running efficiently and effectively, the software is necessary for calculating the total Emission of CO_2 yielded by vehicles that GOS can absorb. Since GOS holds vital roles in controlling air pollution, it must be planned in detail but easy to do by concerning its variables. In short, software that can conduct fast calculations with reasonable accuracy is urgently required. The background above has underpinned this study to determine the most appropriate plant for controlling air pollution in the industrial area and highway and develop software for planning the need of GOS in the urban city.

2. Methods

This research aimed to investigate the most suitable types of plants for eliminating air pollution around the cement factory area in Bogor City. Identification and evaluation were employed toward seven kinds of plants dominantly seen in that area. The assessment criteria for assessing the ability of plant in absorbing pollutant gas covered the physical features of the plant as follows: the density level of tree-crown (A1), plant combination (A2), the thickness level of a leaf (A3), whole leaves (A4), and plant distance (A5). In the meantime, the physical features that can be applied to assess the capacity of the plant in adsorbing dust particles comprise the roughness of leaf surface structure (B1), leaf width (B2), the density level of tree-crown (B3), the texture of stem skin surface (B4), and the density level of twigs (B5).

The density level of tree-crown affecting the effectiveness of substance filter of an air pollutant is measured based on the percentage of total light blocked by the trees. Plant combination is determined based on the existence of plants together with bushes, shrubs, and ground cover plants. The thickness level of the leaf is quantified based on the shapes of intervenium, whether it is thin like a membrane, thin like paper, soft thin, rigid thin, and skin-like as well as fleshy. The method for estimating the total number of leaves is similar to calculating the density of tree-crown. Plants with dense tree crowns will have more leaves. Meanwhile, the plant distance will be judged as dense when it ranges 2-6 meters. The data were collected in one measurement.

Next, the Factor of Emission, which becomes the essential requirement for developing the software of the GOS plan, was calculated in Bangkalan City. To develop software, the plant's data and its absorption capacity against CO_2 were required for counting the plant capacity of emission absorption. Besides, the data of vehicles, total vehicle, road length, emission factor, fuel economy of the vehicle, and fuel density were demanded to calculate emission load. The factor of Emission (FE) refers to the value/number representing the number of pollutants emitted in the air due to certain activities. The value of FE is stated in the mass of pollutant per unit, weight, volume, and distance or duration of specific activities emitting the pollutant. The emission load is calculated based on the following equation (Pasaribu and Tangahu, 2015).

$$Emission = (n \times L \times f \times \rho) \div FE \quad (1)$$

Notes:

Emission	: emission load of CO_2 (ton/year)
n	: total vehicle (vehicle/hour)
L	: road length (km)
f	: emission factor
FE	: fuel economy (km/L)
ρ	: densities of gasoline 0.63 kg/L and diesel 0.7 kg/L

The data of total vehicle at the end of the year, entire vehicle in the initial projection, the average growth of population per year, and projection period were desired for counting the projection of vehicle. Last, the data of total Emission of CO_2 and total absorption capacity of CO_2 were inputted in planning GOS through the software being developed. The absorption capacity of the plant was required by implementing the following equation.

The absorption capacity of tree = CO_2 absorption x total tree (2)

Thus, residual emission can be calculated under the equation:

Residual emission of CO_2 = A – B (3)

Notes :

A : Total CO_2 emission (g/hour)

B : Total absorption capacity of CO_2 by road GOS (g/hour)

The software was designed using PHP (Hypertext Preprocessor). The open-source software would be supported by all Operating Systems (OS) and various databases.

3. Result and Discussion

3.1 Plants for Controlling Air Pollution

Some efforts for reducing air pollution can involve plants. However, each plant has different abilities to do self-adaptation based on absorbing and accumulating pollutant materials. Accordingly, plants belong to good bioindicators for pollution.

The plant leaves have several functions such as respiratory, obtaining food, managing food substances, and transpiration. Leaves also serve as the accumulator of pollutant substances in the air as they have stomata for absorbing air pollutants (Mukhlison, 2013).

Plants can decrease pollutant gases through the oxygenation process. They produce oxygen so that the pollutant gases around the plants will have a mixing process between oxygen and pollutant gases, thereby cleaning the surrounding air. Trees in diameter 37.5 cm can lose SO_2 by 43.5 pounds per year when SO_2 concentration in the atmosphere reaches 0.25 ppm. Pollutant gases will be absorbed actively by the plant tissue, particularly on its leaves and surface. In addition, plants can reduce metal content in the air, such as tin, nickel, cadmium, and chrome. Jun *et al.* (2005) in Beijing successfully demonstrated that plants could remove pollutant 1,261.4 tons from the air.

Overall, plants refer to effective air absorbers as they can clean and reduce pollution levels through absorption, detoxification, and accumulation. They also can regulate the air metabolism so that the air quality can be improved by releasing oxygen into the air. Plants indeed can reduce pollutants of dust particles. Solid particles suspended in the air can be cleaned by tree-crown through the adsorption and absorption processes. By these mechanisms, the total amount of dust floating in the air will decrease.

To absorb air pollutants, plants must accomplish the following criteria: (a) having fast growth, (b) growing along the year, (c) having dense leaves mass and stem, and (d) possessing haired leaves. Moreover, plants can effectively decrease the pollutant particles as long as they have high trichomes or furry, jagged, or scaly leaves. Furry leaves having rough surfaces could adsorb dust particles flying in the air (Alhamadi, 2013). Meanwhile, the surface of hairy leaves could trap dust and soot effectively, as indicated by dirty leaves in some areas with air pollution cases. Plants with coarse or furry leaves could deposit lead better than the ones with slick leaves. Evergreen plants are recommended for adsorbing particles and dust.

The broader the leaf section, the higher the leaf's ability in adsorbing dust. Plants having pin leaves and big, coarse, and furry leaves have a high level of particulate adsorption. The leaves and twigs of furry plants are suitable for more significant lead and zinc particles adsorption than the slippery-skinned trees.

The ability to clean pollution particles is also determined by the density and structure of vegetation (Septiawan et al., 2017). Multilayer vegetation consisting of some layers of plants such as ground covers, bushes, and trees is more effective in adsorbing particles. Dense vegetation can clear particles well. The selection of plants for particulate adsorber in the air must consider the following characteristics: (1) the plant must be able to topple leaves in a certain period. This property is necessary because leaves shedding will encourage the growth of new leaves, which can filter particulate. As a result, the plants will not die because the particulates cover their leaves surfaces; (2) the plant must have shady and dense tree-crown; (3) the plant must have high resistance as the particulate accumulated on the leaf surface will disturb photosynthesis.

The analysis results upon the dominant plants found in the research site demonstrated that the most suitable types of plants for absorbing pollutant gases were Acacia (*Acacia auriculiformis*), Angsana (*Pterocarpus indicus),* and Kihujan (*Samanea saman*). Those three species of plants had satisfied all assessment standards because their density levels of tree-crown were dense and very dense. The ways to plant them were combined with bushes, shrubs, and ground cover plants. In addition, the plants also contained physical features that could support pollutant absorption, such as having thin and many leaves. The three species of plants were also planted within dense distance.

Table 1. The results of plant capacities for gas pollutant absorption

No	Latin Name	Local Name	The Scores of Assessing the Ability for Pollutant Gas Absorption					% Value	Remark
			A1	A2	A3	A4	A5		
1	*Pterocarpus indicus*	Angsana	4	3	3	4	4	90	Very suitable
2	*Samanea saman*	Ki hujan	4	3	4	3	4	90	Very suitable
3	*Acacia auriculiformis*	Acacia	4	2	3	4	4	85	Very suitable
4	*Mimusops elengi*	Tanjung	4	3	3	3	3	80	Suitable
5	*Mutingia calabura*	Kersen	3	1	4	4	4	80	Suitable
6	*Terminalia cattapa*	Ketapang	3	1	4	4	4	80	Suitable
7	*Erythrina crista-galli*	Red Dadap	2	2	2	2	4	60	Less suitable

Notes: A1 = the density level of tree-crown, A2 = plant combination, A3 = the thickness level of leaves, A4 = total leaves, and A5 = plant distance

Table 1 depicts the conditions that plants could reduce air pollutants through the diffusion process by dispersing air pollutants more widely using tree-crown. When the tree has sufficient height, the tree-crown can turn the wind blow to the air more widely. Consequently, the concentration of pollutants will decrease. Besides, more leaves combined with bushes, shrubs, and ground cover plants would optimize the absorption process through the leaf tissue and stomata. Plants with thin leaves have a better capacity for pollutant absorption compared to the ones with thick leaves. In general, plants with thick leaves contain thick tissues that are very difficult to penetrate by pollutants. Furthermore, the dense structure and distance among plants had caused them to conduct better absorption, adsorption, diffusion, and deposition processes against pollution.

Aji et al. (2018) research claimed that Angsana (*Pterocarpus indicus)* plant could accumulate Pb approximately 1.12-12.38 $\mu g/m^3$. Consequently, Pb inside Angsana leaves achieved 1000 ppm ($\mu g/m^3$). Meanwhile, Kihujan, Kersen, and Acacia plants gained better capacities of CO_2 absorption. Chauhan (2010) exposed that air pollution resulted from vehicles affected the quality of air ambient and pigment of trees. In the meantime, the results of assessing the plant capacity to absorb dust are described in Table 2. All plants dominantly found in the research site were proper to absorb dust particles within the absorption level around 65-70%.

Table 2. The results of assessing the plant capacity for dust adsorption

No	Latin Name	Local Name	The Score of Assessing the Ability for Dust Adsorption					% Value	Remark
			B1	B2	B3	B4	B5		
1	*Pterocarpus indicus*	Angsana	1	2	4	3	4	70	Suitable

No	Latin Name	Local Name	The Score of Assessing the Ability for Dust Adsorption					% Value	Remark
			B1	B2	B3	B4	B5		
2	*Samanea saman*	Ki hujan	1	1	4	3	4	65	Suitable
3	*Acacia auriculiformis*	Acacia	1	3	4	3	3	70	Suitable
4	*Mimusops elengi*	Tanjung	3	2	4	2	3	65	Suitable
5	*Mutingia calabura*	Kersen	4	1	4	2	4	75	Suitable
6	*Terminalia cattapa*	Ketapang	2	3	3	2	4	70	Suitable
7	*Erythrina crista-galli*	Red Dadap	2	2	2	3	4	65	Suitable

Notes: B1 =the roughness of leaf surface structure, B2 = leaf width, B3 = the density of tree-crown, B4 = the surface structure of stem skin, and B5 = the density level of twig

Plants with dense and massive tree-crown were able to adsorb particles better and more effectively than those with open tree-crown (Aji, 2018). Besides, the rough surfaces of stem and twig structures influenced the ability of plants to absorb the particles. Twigs and stems of plants with rough surfaces could absorb particles better than the ones with the smooth structure of the plant. Plants consisting of dense twigs could adsorb pollutant particles better than those with a low density of twigs (Septiawan *et al*., 2017).

3.2 Software for Calculating the GOS Needs

PHP (Hypertext Pre-processor) was employed to design software for planning the need of GOS in the urban city as the research objective. PHP refers to a programming language in the script form used for processing data and delivering them to the web browser to be changed into the codes of HTML. PHP is widely implemented because it can develop a complex web application with high stability and speed. To build a website through PHP, several requirements were involved as follows:

1. A web server application (in this context, the researcher applied PHP *web hosting*);
2. PHP programming language;
3. *Database* (this software was designed using MySQL);
4. *Browser* (Microsoft Internet Explorer, Mozilla, Opera, , and others);
5. *Text Editor* (for creating tutorial).

Table 3 presents the results of calculating the residual emission that would be inputted as the data for developing software to calculate the needs of GOS for air pollution reduction. The highest residual emission occurred in Mlajah and Kemayoran Districts. Meanwhile, the negative value of emission could be found in Martajasah Village, indicating that this village could reduce the total emission in the air.

Based on Table 3, the software was developed for counting the sufficiency of GOS needs to eliminate air pollution. To calculate the adequacy of GOS needs, the data regarding research sites, collection time, total vehicle, total vehicle emission, and total emission absorption of trees were then inputted in the developed software. As a result, engineering can be carried out for minimizing the values of residual emission

Table 3. The calculation of residual emission (kg/week)

No	Village/Urban Village	Total Emission (kg/week)	Total Plant Absorption per Week (kg)	Residual Emission (kg/week)
1	Langkap Village	17,104.0	4,299.1	12,805.0
2	Burneh Village	41,924.6	624.0	41,300.6
3	Tanjung Urban Village	39,767.1	679.1	39,088.0
4	Martajasah Village	350.4	948.1	-597.7

No	Village/Urban Village	Total Emission	Total Plant	Residual
5	Mlajah Urban Village	79,816.9	10,228.8	69,588.2
6	Kemayoran Urban Village	73,229.8	7,995.5	65,234.3
7	Pengeranan Urban Village	17,710.0	1,208.3	16,501.7
8	Pejagan Urban Village	48,167.5	1,431.4	46,736.1
9	Kraton Urban Village	29,603.9	14,510.4	15,093.5
10	Demangan Urban Village	33,232.2	8,446.1	24,786.1
11	Bancaran Urban Village	20,204.8	1,147.8	19,057.6

The feature of software adjusted the types of data. For instance, the menu of GOS has the features of the plant, GOS registration, GOS planting, as well as the report of plant and urban village detail absorption, the report of plant and urban village recapitulation absorption, the report of plant and its recapitulation absorption, and the report of total Emission and absorption.

Through this web application-based software, the resulted emission at a specific location can be noticed. The development of a vehicle's emission level can be comprehended and considered the materials for planning GOS. Hence, the software developed in this research can be used as an information system to control the effects of vehicle emissions. Figure 1 demonstrates The Display of Software that had been created.

Figure 1. The display of software

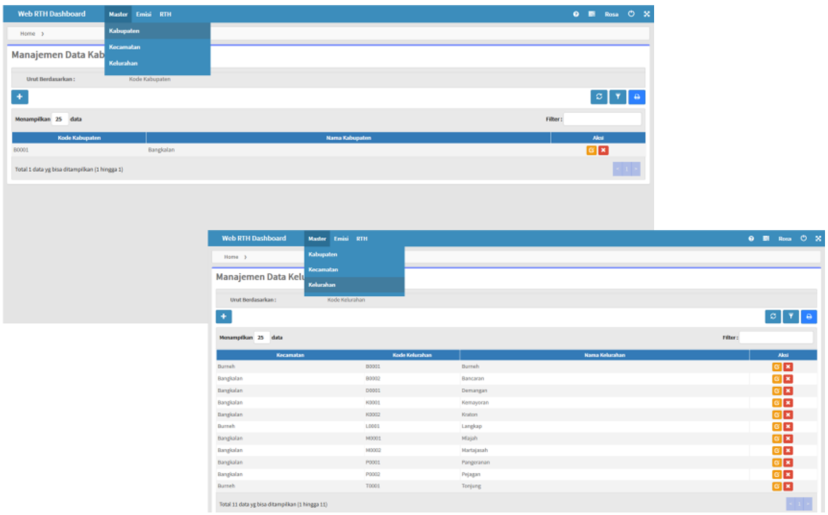

Figure 2. The Display of Software Whilst-Operation

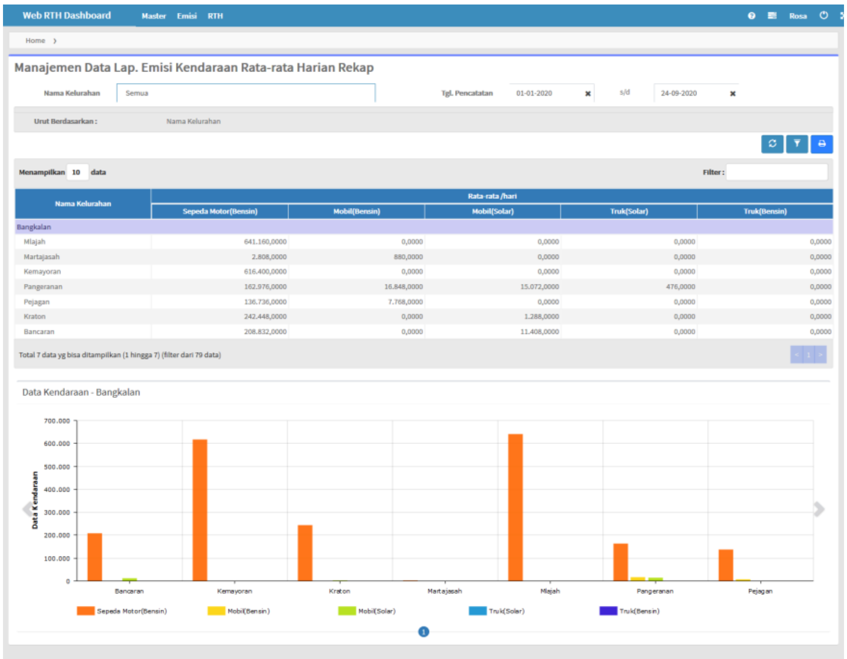

Figure 3. The Display of Software Post-Operation

4. Conclusions

Three out of seven species of dominant plants that had been observed were very appropriate for absorbing pollutant gases, i.e., Angsana (*Pterocarpus indicus*), Kihujan (*Samanea saman*), and Acacia (*Acacia auriculiformis*). All the seven trees being observed indicated suitability for adsorbing dust particles, i.e., Angsana, Kihujan, Acacia, Tanjung (*Mimusops elengi*), Kersen (*Mutingia calabura*), Ketapang (*Terminalia cattapa*), and Red Dadap (*Erythrina crista-galli*). They had adsorption ability by 65-75%.

The results of GOS sufficiency calculated manually showed compatibility with the ones calculated by software developed. Accordingly, the usability of software could be actualized, thereby saving time for planning the GOS needs. The conclusions describe the answers to the hypotheses and/or research objectives, or scientific findings obtained. The conclusion does not contain a repeat of the results and discussion but rather a summary of the findings as expected in the objectives or hypotheses. If necessary, at the end of the conclusion can also be written things that will be done related to further ideas from the research.

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