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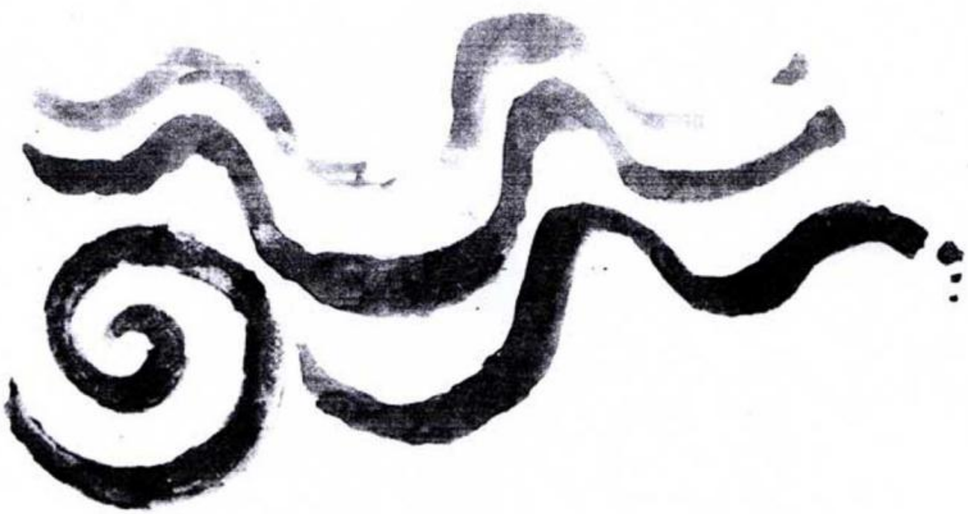

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Furry climbing vegetation as parts of building materials

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Abstract

Since particulate concentration has rapidly increased caused by the use of motorized vehicles, buildings located adjacent to traffic are suffer from this type of pollution. Earlier study which showed that solid and massive barrier was capable of reducing some level of noise pollution caused by traffic and a study on vegetation which showed that this object could reduce some pollutants, lead to a study on climbing vegetation. Solid and massive obstruction covered with climbing vegetation is a study of their capability to reduce particulates. The results show a strong indication that furry climbing vegetation is capable of depositing more particulates compare to those of the waxy ones. This obstruction which acts as fence is also capable of reducing particulate concentration of up to 40 %. Therefore, the use of furry climbing vegetation is suggested to be parts of building materials for building adjacent to traffic.

Introduction

The use of motorized vehicles has greatly increased the level of pollution, not merely gaseous pollution but also particulates and sound pollution. Many research has been carried out to seek any possibilities of attenuating gas pollution as it is considered to have immediate impacts on live. But very limited research has been conducted to meet the solution of particulate and sound pollution. This could be of any reasons, but one of potential reason is no awareness of particulate and sound pollution as dangerous pollutants. This isn't entirely correct. Similar to that of gas pollution, particulate and sound pollution cause detrimental effect on human but it comes gradually. This is considered to be more dangerous when human does not aware of the cause and effect and thus does not make any effort to tackle.

Particulate pollution which is very light and delicate can be inhaled through respiratory systems and deposited deep down on the lung tissue. Particulates with diameter smaller than 10 μm which are among the most harmful of all air pollutants because of their capability to evade the respiratory system's natural defenses and lodge deep in the lungs; can cause lung cancer and bronchial asthma which incubate for long period. Whilst, sound pollution probably do not have direct effect on the hearing process, but it has indirect effect on human emotion and quality of live. An obvious example is when human have difficulties to focus on their activities or lack of relaxes time because of constant sound pollution of their surrounding. Undoubtedly, this will effectively degrades quality of live.

Buildings built adjacent to traffic-generated pollution are potential receivers of both particulate and sound pollution, and thus inhabitants of the buildings. The most effective solution for reducing this type of pollution is to eliminate the source. However, once efforts to eliminate the source are meaningless, the next stage is to block the medium of transmission. This means to put screening between street and buildings to trap the pollutants. Within specific climate of warm humid of Indonesia, the use of such screening creates conflicting needs between pollutant reduction and natural ventilation requirements. What could be the most effective screening, which traps the pollutants without impeding the entire airflow for natural ventilation?

A preliminary study on solid and massive obstruction of particular height, i.e. 1.1 to 1.3 meters, has quite significant capability on reducing traffic noise pollution (Mediastika, 2000). However, this type of barrier would not significantly reduce the entry of particulates into building since it does not covered with particular surface that will encourage particulate deposition. The use of vegetation to enhance barrier performance in reducing both sound pollution and particulates is considered in this study. Prior to this study, a study on low growing vegetation (i.e. shrubs) is conducted (Mediastika, 200). However, this showed rather insignificant solution. Thus, the use of other types of vegetation that fulfils some requirements as described below will be studied.

Objectives

The objectives of this study is to see more detail capability of vegetation especially those that will blends beautifully with solid and massive obstruction to perform both as sound and particulate pollution reduction.

Theoretical approach in using particular type of vegetation

The ability of particulates to remain suspended in the air depends essentially on particle size, shape and density. Large particles fall rapidly because of gravity. Particulates within this type are usually larger than 20 μm and its deposition will create a nuisance on surfaces. More delicate particulates will be removed from the air by impaction then followed by deposition. Impaction occurs when the flowing of the air that carried particulates impacts on an obstruction. Earlier studies showed that impaction processes would be greatly achieved when the air blocked by solid and massive obstruction. This is because the air will lose some of its energy and refracted upward because of the solid obstruction, whilst the particulates then drop and deposit either on the ground or on the surface of the obstruction. There is also benefits in using solid obstruction since earlier study (Mediastika, 2000) showed that this type of obstruction would effectively attenuate sound pollution. Therefore the use of solid obstruction is still proposed in this study.

Apart from solidity and massiveness of obstruction, surface condition of obstruction that encourage and hold particulate in place is also important to be considered. Earlier study of Schneider et al (1999) showed that rough surface will deposits more particulates than shiny surface. Considering this aspect, since earlier studies also showed some prospective solution in reducing pollutant such as gaseous pollution, the use of vegetation is postulated to be the solution of this problem. Some benefits are also postulated to gain since vegetation consists of leaves that covered with natural layer such as furry or hairy and waxy (wax covered surface). However, a negative hypothesis appears when earlier study showed that waxy surface of leaf would not easily melt under solar radiation, thus would not provide sticky surface for effective deposition. This is because leaf waxes contains natural cellulose which act as ethyl cellulose that increases stiffness and reduce wax melting points [Bennett, 1944]. Another benefit in using vegetation is the capability of this object to enhance the appearance of buildings.

Since the effective height of solid and massive obstruction to perform as sound barrier whilst also make air flow for natural ventilation possible has been defined, the height of vegetation that will cover the obstruction is practically been defined. Type of vegetation that blends with this obstruction seemed to be climbing vegetation. Once it is grown on a surface, the vegetation will grow following the shape of the surface and finally covered the whole of the surface. Thus, the result is a solid and massive obstruction covered by climbing vegetation (Figure 3).

Methodologies

Methodologies carry out in this study are as follows: reference study to find and redefine possible obstruction materials, sorting and selecting climbing vegetation referring to theoretical approaches and field conditions, and closed by field examination.

Sorting and selecting climbing vegetation for experiment

Indonesia is a tropical country with a huge variety of fast-growing vegetation. The use of local climbing vegetation will save time and cost, even though it may be difficult to find climbing vegetation which is able to reduce pollutants to the extent required. The selection climbing vegetation is to be according to the following criteria:

- local species;
- durability;

- ease of growth, maintenance and regeneration;
- leaf characteristics (sticky, furry or shiny surfaces);
- aesthetic appeal.

Because of limitation in some aspects, the effects of some microclimatic conditions, particularly rain, could not be studied in this research. Therefore, the results of field experiment would then only show the capability of climbing vegetation to reduce fine airborne particulate in the dry season. However, even in the dry season, moisture is present on the leaf surface, in the form of dew. The presence of dew in the morning will make the particles deposited the day before stick more strongly to the leaf surface. It was postulated that a compound of fine particulate matter and dew would perform in a similar manner to an adhesive. When there is no action to wipe the particulate matter that sticks to the leaf surface, the deposition process will occur continuously until the leaf fades (due to thick particulate layer which impedes photosynthesis) and falls to the ground [Grace, 1977 and Mathew, 1998]. The presence of dew over the leaf surface probably enhances the capability of vegetation to reduce particulate matter, as it prevents particulate resuspension as particulates adhere more strongly to the leaf surface.

Preparation for the experiment

After a selection of some climbing vegetation that fulfil requirement, there are four type sort out from the first selection: Allamanda catharica, Stephanotis floribunda, Monstera deliciosa, and Scindapsus sp. Limitations on resources then narrowed the selection to at least one species per leaf type (shiny and furry). The second selection was then based on availability in the market and cost. The second selection produced two species: Scindapsus sp. and Stephanotis floribunda. A laboratory research to observe the surface anatomy of the leaf was conducted to prove the anatomy surface of either furry or waxy.

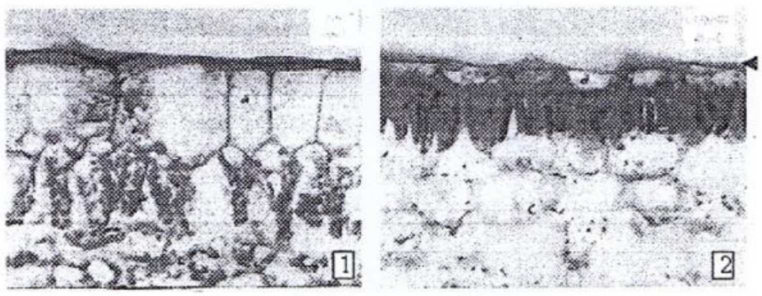

Fig 1: Leaf anatomy of 1. Scindapsus sp. and 2. Stephanotis floribunda. The arrow shows furry layer over the leaf (Source: Mikro teknik UGM).

The Experiment

The experiment aimed to explore capability of climbing vegetation to reduce particulates pollution and different leaf surfaces capability to lodge particulates: shiny (waxy) surfaces and furry surfaces. Earlier research suggested that different types of leaf surface would probably result in different amounts of particles being deposited (Grace, 1977). A furry surface was predicted to lodge more particles due to its roughness (Mathew, 1998). This was proved by Schneider, who found that the presence of a rough surface would encourage slightly more particulate matter to be deposited than on a smooth surface (Schneider, et al, 1999). An earlier prediction that waxy surfaces would lodge more particles caused by stickiness was not always borne out. Leaf waxes, which contain ethyl cellulose, do not easily melt even at high levels of solar radiation (Bennett, 1944).

As mentioned, two selected species were used for this experiment. Particulates concentrations before and after the planting of these were measured by the Bureau of Environmental Health (*Balai Teknik Kesehatan Lingkungan/BTKL*) with equipment named Low Volume Air Sampler (LVS), based on time and measurement points specified by the author. This equipment is broadly use to measure concentration of fine particulates.

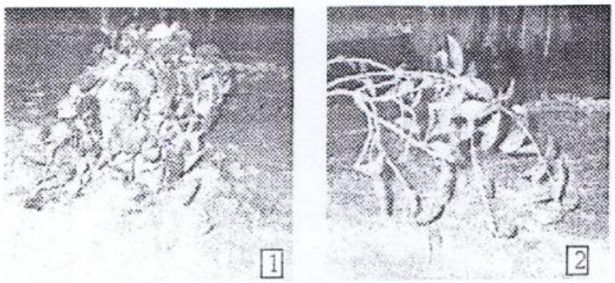

Fig 2: Two species of the selected climbing vegetation
1. Sirih gading (Scindapsus sp.): thin shiny leaves
2. Stephanut (Stephanotis floribunda): thin furry leaves

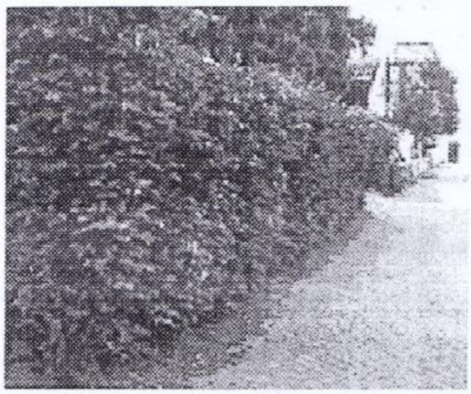

Fig 3: Climbing vegetation after planting over a solid and massive obstruction act as fence

Figure 2 shows the species for fields experiment before planted over a solid and massive obstruction. Whilst Figure 3 shows one of the species after planting. Several LVSs devices were used together to measure particulate matter concentration at certain points at the same time. One LVS was used to measure the street concentration. Two LVSs were used to measure the concentration beyond solid and massive obstruction covered by Scindapsus sp and Stephanotis floribunda.

Results

Table 1 Experiment result of climbing vegetation performances to reduce particulates

Measurement points		Particulates concentration (µg/m³) on day: (measured over 8 hours from 0800 to 1600, the reading taken at 1600)		
		1	2	3
Street		69	81	78
Beyond Vegetation	1	48	67	71
	2	40	56	44
		Weather conditions (averaging from 8 hours, from 0800 to 1600) :		
Temperature		30.2 °C	31.3 °C	29.7 °C
Humidity		82. 5 %	80.5 %	78.5 %
Wind speed		1.10 m/s	0.68 m/s	1.05 m/s
Wind direction		West	West	West
Rain level		0 mm	0 mm	0 mm

Key: Climbing vegetation 1: Scindapsus sp; climbing vegetation 2: Stephanotis floribunda

Table 2 Particulates concentration in percentage to compare between street and after obstruction

Measurement points		Particulates concentration in percentage (comparison between street and beyond obstruction)		
		1	2	3
Street		100%	100%	100%
Beyond Vegetation	1	70% (-30%)	83% (-17%)	91% (-9%)
	2	58% **(-42%)**	70% **(-30%)**	56% **(-44%)**

In order to strengthen the result of particulate concentration reading, three leaves of each species were taken randomly to laboratory. The amount of particulate deposition is then to be scaled using analytical scale. The leaves were washed carefully before starting the experiment, so only particulates generated during the experimental period were deposited on the leaf surfaces. The results of particulate deposition on each leaf can be seen in Table 3.

Table 3 Amount of particulate deposition on each leaf. The arrow show when furry leaf surfaces deposit more particulates

Days	Sample (C1)	PM mg	Leaf area mm^2	PM mg/mm^2
#1	Scindapsus sp.	7.2	4920	**0.001465447**
#2	Scindapsus sp.	1.4	4128	**0.000329457**
#3	Scindapsus sp.	2.1	4224	**0.000487689**

Sample (C2)	PM mg	Leaf area mm^2	PM weight/mm^2
Stephanotis floribunda	1.7	2716	**0.000618557**
Stephanotis floribunda	1.4	2082	**0.000662824** ←
Stephanotis floribunda	2.4	2140	**0.001107477** ←

Discussion

Weather conditions

Throughout the experimental period, the wind speed and wind direction according to the Indonesian Bureau of Meteorological and Geophysics was 10 m/s NW. However, local building decreased the speed and changed the direction as can be seen in Table 1. From this table, it can be seen that temperature and relative humidity did not vary much throughout the experimental period. Any effect that temperature and humidity might have on particulate reduction could therefore not be assessed. However, the wind speed and wind direction did vary. Earlier study, which showed that a strong wind would disperse airborne particulate matter to a wider area, thereby reducing concentration (Harrison, et al, 1997), was borne out in this field experiment. At the highest wind speed of 1.10 m/s, the street concentration was found to be the lowest. In the case of wind direction, it can be seen that, wind direction (West) was always parallel to the street throughout the experimental period. The relation between wind direction and particle concentration was difficult to study, since within the similar direction (i.e. West) the particulate concentrations varied. From this, it can be seen that wind direction has a less significant effect than wind speed. The effect of rainfall was not studied since the whole experiment were conducted in the absence of rainfall.

Vegetation conditions

Table 2 showed that during the whole experiment, particulates beyond obstruction covered by climbing vegetation 1, i.e. Stephanotis floribunda were always lower than those of climbing vegetation 2, i.e. Scindapsus sp. Stephanotis floribunda reduce particulate concentration by up to 40 %. Whilst result on the amount of particulate deposited on leaves surface shows that there were two occasions when Stephanothis floribunda deposits more particulate out of three times of measurements. This leads to a strong indication that furry surface deposits more particulates

Conclusion and Recommendation

As an early stage of research, there were indications that particulates can be reduced by using particular types of vegetation. The principle of particulates removal was based on particulate behaviour specific to environmental conditions. Field experiments indicated that at low wind speeds, particulates could be trapped and deposited on the surface of climbing vegetation covering solid and massive obstruction. The reduction values are believed to have a relationship either directly or indirectly to environmental conditions particularly wind direction and rain. However, no conclusive evidence was found for this. This is mostly due the limited data available and by methodological limitations. It was not possible to fully observe the specific surface of the leaf related to its capability to deposit particles in the presence of rain and different wind speed. This limits further analysis on the relation and the effects of these environmental conditions on particulate deposition on leaf surface. However, it can be seen that with stable temperature and humidity throughout the experimental period which is characteristic of the region, the effect of variation of these two climatic factors on the manner of particulate removal can be disregarded. Given that the range of local wind speeds in most Indonesian cities is narrow (0 m/s to 2 m/s), its effects on the manner of particulate removal will not be as significant as in regions with a wider range of wind speeds.

It was borne out in the field trials that in typical climatic conditions as occurs in this research, furry climbing vegetation was capable of reducing particulate concentration by up to 40 %. Furry leaf surfaces also tended to have more particles deposited on them than shiny leaf surfaces. Therefore the use of furry climbing vegetation is strongly suggested to be used with conjunction to solid and massive obstruction as parts of building material for those located adjacent to traffic.

However a further and deeper study of this object is of importance in order to show more detail ability of this object, especially with regard to climatic conditions.

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