Study of the Effectivity of Several Tree Canopy Types on Roadside Green Belt in Influencing The Distribution Vertically and Horizontally of CO gas Emitted from Transportation Activities to Vicinity of The Road

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Abstract. High volume of vehicle leads to the increase of emission of pollutants level in major cities of Indonesia. Carbon monoxide (CO) is categorized as the main gas pollutants from transportation that are harmful to human health. Plants could be used as roadside green belt to reduce the level of pollutants emitted from the transportation. The purpose of this research is to determine tree canopy type that effectively reduce CO gas concentration, to determine the relation between tree canopy types and pollutant distribution vertically and horizontally. The research was conducted on roadside green belt of Jagorawi Highway, especially on the plot of glodogan (Polyniaceae fragrans), plot of mahogany (Swietenia macrophylla) and a control plot (open filed). Air sampling was conducted to measure the concentration of CO at three elevation 1.5 m, 5 m, and 10 m at each distance 0 m, 10 m, and 30 m. Concentration of CO was analysed using Iodometri method. Vertical distribution of CO gas shows that the concentration increases with the increasing of sampling elevation on the plot of Polyniaceae fragrans and Swietenia mahogany, but the control plot shows the opposite. Horizontal distribution shows that the concentration decreases at the distance 10 m on the plot of Polyniaceae fragrans and Swietenia mahogany, but the concentration increases again at the distance 30 m. At the distance 10 m and an elevation 1.5 m, the highest decline percentage of CO occurs on the plot of Swietenia mahogany (45.1%), on the plot of Polyniaceae fragrans is just 22.2%, while in control plot, it increases by 2.2%. At the distance 30 m and elevation 1.5 m, the concentration increased again on all of the plots. Thus roadside green belt with a thickness 10 m is not effective in reducing the concentration of CO at the distance 30 m or in residential areas.

1. Introduction
The increase of population resulted in high demand for means of transportation as migration tool of both people and goods from one to another place. Based on the data of Badan Pusat Statistik Kota Bogor (2013), the population of Bogor city in 2012 increased by 3.87% from the previous year. While the number of public transportation in Bogor city has reached 4,644 units in 2012, it increases by 3.61% from the previous year. The number of vehicle certificate issued by the Bogor Police is 17,112

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for passenger cars, 2,935 for freight cars, 142 for buses and 55,444 for motorcycles. High volume of vehicle, the high pollutants released so that the air pollution level in major cities of Indonesia, including Bogor continues to rise.

Pollutants could be defined as chemicals which are added or inserted into the atmosphere through human activity causing the increase of substances concentration (Krupa 1997). Pollutants could be classified into primary pollutant and secondary pollutant. The primary pollutant is a pollutant directly released into environment from natural processes and human-related activities. Primary pollutants could be deposited onto the surface of the ground or carried by the wind and fused with other primary pollutants to form secondary pollutants. Pollutants could be in the form of gas and solid particles. The negative impact of air pollution is harmful for human health, vegetation, ecology and poverty. Therefore, air pollution should be controlled in an integrated manner from a variety of approaches in order to be fulfilled healthy air quality.

Based on Government Regulation Number 41 Year 1999 which establishes air quality standards, types of air pollutants quality standard has been set including \( \text{SO}_2 \), \( \text{CO} \), \( \text{NO}_2 \), oxidants (\( \text{O}_3 \)), hydrocarbons, PM10, PM22, Pb and Dust. To achieve the quality standard of air quality, emission limitation and reduction of pollutants from the air is one of effective approach. Pollutants that have been released into the atmosphere could only be reduced by vegetation in green open spaces, and reduced by natural processes such as rain washing pollutants in the atmosphere or the flow of wind diffusing pollutants into the wider atmosphere so that the concentration of pollutants could be decreased.

Pollutants produced from combustion of fossil fuels are gas emissions of vehicles such as \( \text{CO} \), hydrocarbons (HC), \( \text{SO}_x \), \( \text{NO}_x \) and particles. The most harmful pollutants are the particles, \( \text{NO}_x \), \( \text{SO}_x \), hydrocarbons, and the lowest is carbon monoxide (CO) (Darmono 2001). Even though CO is less toxic than other pollutants, CO is categorized as the main gas pollutants which reach almost half of all existing air pollutants. CO is a colorless, odorless and tasteless gas emitted from combustion process, so that its existence is not recognized by humans. CO could be harmful to health because it could combine with haemoglobin in the blood to form COHb (Krupa 1997).

One of the most important green spaces in the city is roadside green belt. Roadside green belt consists of vegetation planted outside the roadside or in median of the road. Vegetation on roadside green belt not only provides the aesthetics and comfort, but also it reduces the negative impacts of transportation activity such as air pollution and noise into the environment (Gary 2014).

Naturally diverse forms of tree canopy consist of rounded, cylindrical, umbrella, palm, heart, and fan shape (Cheng, 2011). Moreover, the density of the leaves will determine the shade of the tree canopy. In planning roadside green belt, it is necessary to apply the form of trees which effectively reduces air pollution emitted from the highway. Therefore, the effectivity of various tree canopy types on roadside green belt in reducing the concentration of air pollution should be investigated, especially CO gas in the vicinity of the road by examining the distribution of pollutant concentrations horizontally and vertically.

### 2. Literature Review

Pollutants produced from a varied source. Krupa (1997) suggests that the pollutants could be produced from static or dynamic sources. Static source is a source of pollutants that has a stationary position, such as a volcano or a factory chimney. Dynamic source is a source of pollutants that could move the position, for example a motor vehicle. Pollutants generated from the motor vehicle have multiple mechanisms of distribution, which spread to sideways and upwards (diffusion).

Pollutants produced from combustion of fossil fuels are emissions of motor such as \( \text{CO} \), hydrocarbons (HC), \( \text{SO}_x \), \( \text{NO}_x \) and particles. The toxicity of the pollutants is different. The most harmful pollutants to health are the particles, followed by \( \text{NO}_x \), \( \text{SO}_x \), hydrocarbons, and the lowest is carbon monoxide (Darmono 2001). Even though they are less toxic than other pollutants, but carbon monoxide (CO) is categorized as the main pollutants that reach almost half of all existing air
pollutants. CO is colorless, odorless and tasteless gas, so that its existence is not recognized by humans. CO tends to diffuse from the near-surface soil and fills an enclosed space which can be very harmful to humans. CO could be harmful to health because it could combine with haemoglobin in the blood to form carboxyhaemoglobin (COHb). CO is highly toxic at concentrations greater than 1000 ppm, it could cause asphyxiation. It is the condition when body and brain in shortage of O2 because blood has bind CO (Krupa 1997). In addition, CO could affect the nervous and cardiovascular systems such as hardening of the arteries. This can lead to disruption of the blood supply to parts of the body such as the heart muscle that cause chest pain until death.

To reduce the level of pollutants in the air, several ways could be applied, either reduce pollutants at source (effluent) or reduce pollutants in ambient air. In order to reduce pollutants at source, some ways could be applied are improve the combustion process, select raw materials that do not produce high levels of pollutants, and use better technology. In order to reduce the level of pollutants at the source, the biologic mechanisms, namely the use of plants and vegetation is generally applied.

Plants as landscape elements of the road, either tree, bush or shrub has the potential and important role in reducing air pollutants. Plants have the potential morphologies such as leaf shape, leaf thickness, number of stomata, trichomes and others which support the potential absorption of air pollutants. The process of gas absorption by plants occurs mainly on leaves. Most of the gas exchange occurs in the leaf through the stomata (Gardner et al 1991). The ability of plants to absorb the gas from the air especially could be known from plant metabolic processes such as photosynthesis, respiration, transpiration, and stomata conductivity. According to Grey and Deneke (1978), species with a moderate to high stomata density has potential of good absorber of pollutant.

The streets in the city or on the highway have been completed by the roadside green belt, either at the roadside or median of the road. A variety of plants that exist on roadside green belt could be optimized to reduce the levels of pollutants generated by motor vehicles. An adequate existences of green open space with the type of vegetation that can absorb pollutants effectively becomes a very important requirement for the health and comfort to urban community.

3. Objectives of Research
This research has a common goal to study differences in the ability of different tree canopy to absorb CO gas pollutant, while the specific objectives are:
- to determine tree canopy type that effectively reduce CO gas
- to determine the relation between tree canopy types and pollutant distribution vertically and horizontally

3.1. Expected Output
The results of this study are expected to give an idea of the importance of plant selection with tree canopy which is effective in reducing pollutants on roadside green belt, and it could be useful for guidelines in the selection of plants, especially tree, in the preparation of planting plan on roadside green belt.

3.2. Activity Overview
Similar study has been conducted is the research related to the function of vegetation in reducing the levels of pollutants in ambient air. Aspects that have been studied include species with high capacity to adsorb pollutant particles of lead (Pb), nitrogen oxides (NOx) as well as the width of the green belt relationships which are effective in reducing pollutants. The new aspect had been examined is the relationship between the type of tree canopy and its effectivity in reducing CO gas. The result of this research activity is expected to complete the preparation of guidelines for plant selection, especially trees that effectively reduce CO gas for roadside green belt.
4. Research Methods

4.1. Location and Time of Research
To conduct the research regarding the relation between canopy shapes and reduction of pollutants’ concentration in vicinity of the road had been conducted in the end of June 2015 on roadside green belt of Jagorawi Highway in Cibubur from km 8 - 12.5 on Jakarta – Bogor track. Air sampling was conducted for measurement of CO gas on June 11, 2015.

Preparation of tools and materials for CO measurement of air quality parameters as well as the analysis was conducted in the laboratory of Environmental Research Centre (PPLH) LPPM IPB.

Table 1. Canopy shape of green belt and location at Jagorawi Highway

| Canopy shape | Tree species                  | Position (km) | Sampling time/ Replication                  |
|--------------|-------------------------------|---------------|--------------------------------------------|
| Rounded      | Mahoni (*Swietenia macrophylla*) | 8.800         | 10 - 11 am, 01 - 02 pm, 04-05 pm           |
| Cylindrical  | Glodogan bulat (*Polyathia fragrans*) | 9.800         | 10 - 11 am, 01 - 02 pm, 04-05 pm           |
| Control      | Open space                    | 12.500        | 10 - 11 am, 01 - 02 pm, 04 - 05 pm         |

4.2 Implementation of Research

4.2.1. Measurement of CO Gas Concentration
This activity was conducted with air sampling on plot as following: (1) Plot of green belt planted with rounded Mahogany (*Swietenia macrophylla*) (2) Plot of green belt planted with cylindrical Glodogan (*Polyathia fragrans*), and (3) control plot in the area without green belt, open space. In each plot, sampling was conducted at the distances 0, 10, 30 m. Distance 0 m is the edge of road side green belt that close to road curb or at point 5 m from the edge of the road (asphalt). At each point, sampling was conducted at the elevation 1.5, 5, 10 m above soil surface. Air sampling was conducted using Impinger Air Sampler.

![Sampling elevation of air quality measurement](image-url)
4.2.2. Measurement of CO Level in the Laboratory
Measurement of CO was conducted following the method of Iodometri in PPLH IPB Laboratory.

4.2.3. Data Analysis
The effectivity of the reduction of CO gas concentration by each type of canopy will be found by comparing air quality from the results of measurement on green belt with air quality on control plot. The effect of roadside green belt to concentration reduction of pollutant would be formulated through experimental design with three factors: type of canopy of green belt, distance from the road, and the elevation above soil surface. Furthermore, to determine the influence of the experiment factors, the data of CO gas concentration was analysed using ANOVA. If the experiment factor was significant, test of Duncant Multiple Range at the level of $\alpha \leq 5\%$ would be applied. To assess which canopy type better in reducing concentration, the value of concentration reduction rate are compared between plots.

4.2.4. Formulation of Recommendation
Recommendations for the selection of plant type which could be used for planting plan for roadside green belt based on canopy types of plant which has the highest effectivity of pollutant reduction and the relation between the shape of the canopy and reduction of pollutant concentration.

5. Results And Discussions
5.1. Source of Pollutant
Vehicles passing on Jagorawi Highway are categorized as dynamic source of pollutant. At the time of CO gas sampling, the volume of vehicles reached 10.163-13.035 vehicles per hour (Table 2). Table 2 shows the emissions on June 11, 2015 decreased at noon, and then increased again in the afternoon.

**Table 2.** Time of air sampling, total vehicle passed the Highway, and estimation of CO gas emitted by vehicle

| Time of sampling | Total Vehicles | Estimation of CO emission / km (g) | Wind velocity (m/second) |
|------------------|----------------|-----------------------------------|--------------------------|
|                  |                | Polyalthia | Mahagony | Control |
| 10 – 11 am       | 13.035         | 689.163    | 0.3- 0.5 | 1-1.5  | 0.5   |
| 01 – 02 pm       | 13.270         | 617.360    | 0.6-0.7  | 1.5-1.7 | 0.5-0.9 |
| 04 - 05pm        | 10.163         | 769.077    | 1.2 – 1.7| 2-3.1  | 0.5 – 0.6|

Description:
Emission of gasoline vehicle 60 g CO / km, emission of diesel vehicle 0.69 gram CO / km based on Strauss and Mainwaring in Sulistjorini (2009). The vehicle assumed consists of 10% diesel and 90% gasoline type vehicle.

5.2. Concentration of CO in each Plot
Results of analysis of variance showed that concentration of CO was very significantly differ among plots. However the effect of distance from the road, elevation of sampling, and their interaction was not significant to CO concentration. Concentration of CO in *Swietenia mahagony* plot was significantly higher than other plots, but value in *Polyalthia fragrans* plot was not significantly differ against control plot (Table 3). Concentration of CO gas was higher at 0 m or at pollutant source point than other plot. The number of vehicle was the same passed across of all plots, but wind velocity was the fastest in *Swietenia mahagony* plot (1-3.1 m/second). It is probably the higher wind velocity enhanced more CO pollutant distribution to *Swietenia mahagony* plot.
Table 3. Average of CO concentration in the plot of air sampling in several distance from the road.

| Distance (m) | Polyalthia fragrans | Swietenia mahagony | Control/open field | Average |
|-------------|----------------------|--------------------|--------------------|---------|
| 0           | 2896.1               | 7620.2             | 3074.4             | 4530.3  |
| 10          | 2573.0               | 3581.6             | 2919.0             | 3024.9  |
| 30          | 2964.6               | 9065.0             | 3341.3             | 5123.6  |
| Average     | 2811.5\(^b\)        | 6755.7\(^a\)       | 3111.7\(^b\)      |         |

Description. Values which it is followed by different alphabet character is significantly different by Duncant Multiple Range Test at the level of \( \alpha \leq 1\% \).

5.3. The Distribution of CO Gas Concentration

Distribution of CO gas concentration on plot of Polyalthia fragrans is presented in Figure 2. Analysis of variance performed effect of sampling distance and elevation and their interaction to CO concentration were not significant. Vertical distribution shows at the distance 0 m, the concentration tend to increases with the increasing of sampling elevation, at the distance 10 m the concentration at the elevation 10 m is higher than elevation 0 m, while at the distance 30 m, the concentration slightly decreases with the increasing of sampling elevation.

Horizontal distribution at the elevation 1.5 m shows that concentration of CO tend to increases with the increasing of distance up to 30 m. At the elevation 5 m, the concentration decreases at the distance 10, then increases again at the distance 30 m. While, at the elevation 10 m, the concentration decreases until at the distance 30 m.

If the concentration at the distance 0 m as a reference, so that on plot of Polyalthia with the elevation 5 m and 10 m, the concentration decreases at the distance 10 m by 22.2% and 21.6%, and at the distance 30 m and elevation 10 m, concentration decreased by 22.3% (Table 4).

Figure 2. The concentration of CO gas on plot of Glodogan
Distribution of CO gas on plot of *Swietenia mahogony* is shown in Figure 3. Analysis of variance performed effect of sampling distance and elevation and their interaction to CO concentration in Swietenia mahagony were also not significant. Vertical distribution of CO gas shows generally at the distance 0 and 10 m, the concentration tends to decrease at the elevation 5 m and then increase again at the elevation 10 m, while at the distance 30 m, the concentration increases with the increasing of elevation sampling point.

Horizontal distribution of CO gas on plot of *Swietenia mahogany* shows that at the elevation 1.5, 5, 10 m, the concentration decreases at the distance 5 m, and then increases again at the distance 30 m. If the concentration at the distance 0 m as a reference, at the elevation 1.5, 5, and 10 m, the concentration at the distance 10 m declines by 45.2%, 43% and 20.4% respectively, while at the distance 30 m and elevation 10 m, the concentration decreased by 1.4% (Table 4).

**Table 4.** Concentration in distance 10 m and 30 m if concentration at the distance 0 used as reference in each plot of sampling

| Elevation (m) | Distance (m) | Mahagony | Polyathia | control | Mahagony | Polyathia | control |
|---------------|--------------|----------|-----------|---------|----------|-----------|---------|
| 1.5           | 0            | 100      | 54.9      | 119.2   | 102.2    | 107.4     | 134.9   | 105.4   |
| 5             | 0            | 100      | 56.9      | 77.8    | 52.8     | 166.6     | 108.2   | 82.8    |
| 10            | 0            | 100      | 79.6      | 78.4    | 248.2    | 98.6      | 77.7    | 171.2   |

In each plot, thickness of the trees is 10 m, the land use from distance 10 m to 30 m is open space. Especially on plot of *Swietenia mahogany*, the land use at the distance 30 m is residential area. This shows that CO gas concentration decreases with the existence of vegetation. At the distance 30 m, concentration increases, it might be caused by additional CO gas flowing from elevation 10 m. This pattern of CO gas distribution shows that the green belt planted with *Swietenia mahogany* with the thickness 10 m is not quite effective in reducing concentration of CO gas in residential area.
The distribution of CO gas on control plot is presented in Figure 4. Vertical distribution shows that the concentration tends to decrease with the increasing of sampling elevation.

Horizontal distribution shows that at the elevation 1.5 m, concentration is not reduced by the addition of distance up to 30 m. At the elevation 5 m, the concentration tends to decrease with increasing of distance up to 30 m. At the elevation 10 m, the concentration increases at the distance 10 m, then declines at the distance 30 m. If the concentration at the distance 0 as a reference, then the control plots at the elevation 5 m, the concentration decreased by 47% at the distance 10 m, and decreased by 17% at the distance 30 m (Table 4).

If it is compared to the control plot, road side green belt of Swietenia mahogany could reduce the concentration at the elevation 1.5 m and distance 10 m with a higher percentage than Polyalthia fragrans and control.

6. Conclusions and Recommendations
Distribution of CO gas concentration increases with the increasing of sampling elevation on the plot of Polyalthia fragrans and Swietenia macrophylla, but the contrary trend is found in the plot of control.

Roadside green belt of Swietenia macrophylla with rounded canopy type is more effective than Polyalthia fragrans with cylindrical canopy type in reducing CO concentration at the distance 10 m, but concentration rebound at the distance 30 m. Therefore roadside green belt with the width 10 m is not yet effective to reduce CO concentration in residential area.

It is suggested to study CO gas distribution in wider roadside green belt in order to know the minimum width that effective to protect environment at the vicinity of road.

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