Evaluation of Physical Function and Air Pollution Tolerance of Roadside Tree in Bogor Botanical Garden’s Surrounding

A M Febrianti¹ and B Sulistyantara²

¹ Student, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia
² Lecturer, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia

E-mail: ¹andreaneshova@gmail.com; ²bbsulistyantara@yahoo.co.id;

Abstract. Air pollution causes decrease life quality ini urban areas. One solution in reducing air pollution is to use vegetation. The roadside Green Line consists of several types of vegetation, one of the trees. The ecological functions of the tree include pollution absorber. Roadside tree have specific physical appearance to determine its function. Roadside trees as living character that grow in polluted areas have different tolerance levels, one way of measuring tolerance based on biochemical parameters is the Air Pollution Tolerance Index (APTI). APTI can be a performance consideration of a tree type in a habitat of growth. The purpose of this research are to evaluating the physical function of roadside tree, to analyzing APTI. Based on the result of the study, the suitable (very suitable and suitable) physical function of roadside tree for absorbing gas air pollution was 62.78% and for adsorbing particle air pollution was 80.5% of total population of tree around Bogor Botanical Garden. Findings revealed that among 10 plant species are intermediate tolerant to air pollution and 11 plant species are sensitive to air pollution.

Keywords: air pollution, APTI, green path, tree, urban area

1. Introduction
As time goes by, human populations are increasing as well as vehicles. Vehicle releases chemical into the air becoming air pollution. Natural solution to reducing air pollution using the path green path. Green path is one of efforts to overcome air pollution. The Green Line serves as a filter to absorb and intercept the pollutant to reduce its concentration. Plants have various morphologies. This research purposed to evaluate the morphology of the appropriate plant to overcome air pollution and its tolerance to air pollution. Plants with appropriate morphology will increase the effectiveness of its performance and the tolerant crops will be more adaptive to air pollution. Poor Air quality problem can be addressed by planting tolerant plant species. Sensitive plants species could be bioindicator of air pollution.

2. Material and Methods
2.1 Description of study area
Bogor Botanical Garden Outer Ringroad are center part of Bogor City. It surrounded by main road such as Pajajaran St., Otto Iskandardinata St., Juanda St., and Jalak Harupat St. All roads are covered by asphalt and has different length. Juanda St. has 1.68 km length, Jalak Harupat St. has 1.04 km length, Otto Iskandardinata has 0.7 km length and Pajajaran St. has 0.4 km length. These roads are main collector road of Bogor City which had high traffic of vehicles.
Green lane are located along of the road in right and left side. Bogor Outer ringroad had pedestrian path for walking and cycling.

![Figure 1 Bogor Botanical Garden’s outer ring-road](image)

### 2.2 Plant sampling

A total of twenty-two plant species were selected from the urban area, whereas, the same plants growing in Bogor Botanical Garden surrounding. Plants were selected on the basis of presence of visible morphological impacts of pollution on foliage; direction of air flow; plant abundance, and ecological significance of the specific plant species. Matured fresh leaves of selected plant species were collected during the peak crushing time i.e. morning in five replicates. Collected leaves packed in plastic bag and immediately stored in ice storage for the analysis. The plant sampling conducted during July to August 2019.

![Figure 2 How sample was taken](image)

### 2.3 Physical function analysis

Physical function analysis is descriptive analysis using Key Performance Index (KPI) for each criteria. The highest value is 4 and the lowest is 1. The result is calculated by following formula [1]:

\[
\text{Evaluation value} = \frac{\text{Total value}}{\text{Total ideal value}} \times 100\%
\]

The assessment results are differentiated into categories that are very suitable, suitable, less suitable, and not suitable, and counted the percentage of the total type and total existing. The criteria are taken from previous research of tree physical functions.
Table 1 Physical function criteria

| Physical function aspect | Criteria                          | Value                                           |
|--------------------------|-----------------------------------|-------------------------------------------------|
| Gas pollutant absorption | Canopy density [2]                | 1. Very sparse                                  |
|                          |                                   | 2. Sparse                                       |
|                          |                                   | 3. Medium dense                                 |
|                          |                                   | 4. Very dense                                   |
|                          | Thin leaves [3]                   | 1. Thin leave skin-like, elastic                 |
|                          |                                   | 2. Perkamen thin                                |
|                          |                                   | 3. Thin soft                                    |
|                          |                                   | 4. Thin film                                    |
|                          | Amount of leaves [2]              | 1. Very sparse                                  |
|                          |                                   | 2. Sparse                                       |
|                          |                                   | 3. Medium dense                                 |
|                          |                                   | 4. Very dense                                   |
| Particle pollutant       | Trachoma leaves [4]               | 1. Shiny surface, no trachoma                   |
| adsorption               |                                   | 2. No trachoma not shiny                        |
|                          |                                   | 3. Trachoma can be seen with magnifier          |
|                          |                                   | 4. Trachoma can be seen with bare eye           |
|                          | Needle-like leaves, width leaves  | 1. Nanophyl (0.25-2.25 cm²)                     |
|                          | [5]                               | 2. Microphyll (2.25-20.25 cm²)                  |
|                          |                                   | 3. Mesophyll ((20.25-182.25 cm²)                |
|                          |                                   | 4. Macrophyll (>182.25 cm²), needle like leaves |
|                          | Canopy density [5]                | 1. Very sparse                                  |
|                          |                                   | 2. Sparse                                       |
|                          |                                   | 3. Medium dense                                 |
|                          |                                   | 4. Very dense                                   |
|                          | Rough stem texture [4]            | 1. Sleek texture, shiny                         |
|                          |                                   | 2. Sleek texture with lentisel                  |
|                          |                                   | 3. Rough texture                                |
|                          |                                   | 4. Very rough texture, spiked                   |
|                          | Branch density [4]                | 1. Very sparse                                  |
|                          |                                   | 2. Sparse                                       |
|                          |                                   | 3. Medium dense                                 |
|                          |                                   | 4. Very dense                                   |

Category value following KPI method

Very suitable : 100%-81%
Suitable : 80%-61%
Less suitable : 60%-41%
Not suitable : <40%

2.4 Biochemical analysis

Relative water content (%) of the leaf was calculated by following formula [6]:

\[
RWC = \frac{FW - DW}{TW - DW} \times 100
\]

where, FW is the fresh weight, DW is the dry weight of turgid leaves after oven-drying at 80°C for 24 hours, and TW is the turgid weight (mg) after overnight immersion in distillated water in closed-dark room, whereas, total chlorophyll (mg/g) was estimated following Arnon [7] and Chouhan et al. [8]:
Chlorophyll a = \frac{12.7D_{663} - 2.69D_{645} \times V}{1000 \times W} \\
Chlorophyll b = \frac{22.9D_{645} - 4.68D_{633} \times V}{1000 \times W} \\
Total chlorophyll = chlorophyll a + chlorophyll b \\

where, D is the absorbance of the leaf extract at a specific wavelength, V is total volume of the chlorophyll solution (ml), and W is weight of the tissue extract (g). pH of the leaf extract was estimated using pH meter from homogenized 10 g of fresh leaves in 10 ml distilled water. Mixture was filtered and pH was determined after calibrating pH meter with buffer solution of pH 4, pH 7 and pH 9. Ascorbic acid were estimated using iodometri method:

\[ \text{Ascorbic acid} = \frac{V_{I2} \times \frac{V_t}{V_f} A}{W} \times 100\% \]

Where, VI2 is mean volume of Iodium, Vt is total volumeof filtrate , Vf is total used filtrate, A is Equality of I_{2} and ascorbic acid, and W is weight. Results of these four biochemical properties were then subjected to the formula given by Singh and Rao [1], for the calculation of APTI:

\[ \text{APTI} = \frac{A(T+P)+RWC}{10} \]

where A is the ascorbic acid content (mg/g), T is the total chlorophyll (mg/g), P is the pH of leaf extract, and R is the relative water content of leaf (%). APTI is an ideal tool to identify the responses of plants to the pollution load in atmosphere, and it is extensively used in biomonitoring studies.[10][11][12][13][14] On the basis of APTI value plants were categorized as follows; 1–11 as sensitive, 12–16 as intermediate and ≥17 APTI as tolerant.[13]

3. Result and Discussion

3.1 Condition of transportation and ambient of pollution

Road conditions in the outer ring of the botanical garden are paved and can be crossed by two-wheeled motor vehicles and 4-wheel vehicles. As it was known before that the frequency of vehicles passing high on a road would emit large vehicle emissions as well.

The state of the ambient air of Bogor Botanical garden outer ring road from 2015 to 2018 on four parameters increased, one parameter decreased and four remaining volatile. The increasing parameters include H2S, O3, SO2, and Pb. The parameters are decreasing only HC whereas volatile parameters consist of dust, NO2, CO, and NH3. The ambient air Data consisted only of 2015, 2016, and 2018 because in 2017 the environmental service did not perform measurements with these parameters at the same location. In the measured 2015 H2S year measurement of 0.5 μg/m3; In 2016 measured by > 0.004 ppm; And in 2018 measured by 131 ppm. There was a decrease in the ambient concentration of H2S in the period of 2015 to 2016 but experienced a significant increase in the time of 2016 to 2018. Based on the tests that have been conducted by environmental service Bogor city, measured lead rate in the year 2015 of 0.02 μg/m3; In 2016 measured by > 0.05 μg/m3; And in the year 2018 measured by 40 μg/m3. There was considerable improvement over the period of 2016 to 2018.

After the implementation of one way system, there are changes in the vehicle, average vehicle speed, road segment ratio, and road service level. After the application of one way system, the average vehicle speed is increased. At Pajajaran Street, it rises from 22.86 km/h to 42.2 km/h; Otto Iskandardinata Street from 14.63 km/h rose to 39.0 km/h; Ir. H. Djuanda
Street rises from 14.63 km/h to 41.9 km/h, and Jalak Harupat Street rises from 14.78 km/h to 41.7 km. [15]

3.2 Tree physical function evaluation

There are 22 tree species around green path of Bogor Botanical Garden. Those species are spreading in four roads. Population dominated in St. Pajajaran which is 166 trees, following by Juanda Street which is 93 trees, Jalak Harupat Street which is 77 trees, and Otista Street which is 43 trees.

Table 2 Plant species around green path of Bogor Botanical Garden Outer Ring-Road

| Plant species                  | St. Pajajaran | St. Otista | St. Juanda | St. Jalak Harupat | Total | Percentag e (%) |
|-------------------------------|---------------|------------|------------|-------------------|-------|-----------------|
| Agathis damara                | 14            | 6          | -          | 1                 | 21    | 5.54            |
| Arenga pinata                 | -             | 10         | -          | -                 | 10    | 2.63            |
| Artocarpus heterophillus      | 1             | -          | 3          | 4                 | 8     | 2.11            |
| Bauhinia purpurea             | -             | 2          | -          | -                 | 2     | 0.52            |
| Canarium comune               | -             | 1          | 58         | 1                 | 60    | 15.83           |
| Ceiba petandra                | 3             | -          | -          | -                 | 3     | 0.79            |
| Cupresus papuana              | 10            | -          | -          | -                 | 10    | 2.63            |
| Delonix regia                 | 1             | 1          | -          | 3                 | 5     | 1.31            |
| Dillenia indica               | 1             | -          | -          | -                 | 1     | 0.26            |
| Diospyros blancoi             | -             | 2          | -          | -                 | 2     | 0.52            |
| Ficus benjamina               | 1             | -          | 1          | -                 | 2     | 0.52            |
| Lagerstomia speciosa          | -             | 4          | -          | -                 | 4     | 1.05            |
| Magnifera indica              | -             | 1          | 1          | -                 | 2     | 0.52            |
| Michelia champaca             | 6             | -          | -          | -                 | 6     | 1.58            |
| Mimosoph elengi               | 38            | 4          | 6          | 23                | 71    | 18.73           |
| Phoenix roebelini             | -             | -          | 2          | -                 | 2     | 0.52            |
| Pterocarpus indicus           | 1             | 8          | -          | 1                 | 10    | 2.63            |
| Roystonea regia               | -             | -          | 8          | -                 | 8     | 2.11            |
| Schefflera grandiflora        | -             | -          | -          | 6                 | 6     | 1.58            |
| Swietenia macrophylla         | 80            | -          | 10         | 36                | 126   | 33.24           |
| Terminalia mantaly            | 10            | 4          | -          | -                 | 14    | 3.69            |
| Veitchia merilii              | -             | -          | 4          | 2                 | 6     | 1.58            |
| **Total**                     | **166**       | **43**     | **93**     | **77**            | **379** | **100**        |
Results of the analysis using the scoring method of the tree that suitable physical characteristics. The good gas pollution absorbent tree has physical criteria such as solid tree, thin leaf, and has a lot of leaves. The trees belonging to the category are very suitable are *Canarium comunne*, *Delonix regia*, *Pterocarpus indicus*, *Terminalia mantaly*, *Mimusops elengi*, *Swietenia macrophylla*, *Bauhinia purpurea*, and *Cupresus papuana*.

Table 3 Suitability of absorbing gas pollution of selected plant species growing around green path of Bogor Botanical Garden Outer Ring-Road

| Plant species       | Evaluation value (%) | Suitability | Evaluation value (%) | Suitability |
|---------------------|----------------------|-------------|----------------------|-------------|
| *C. comunne*        | 91.6%                | VS          | *D. blancoi*         | 66.7%       |
| *D. regia*          | 91.6%                | VS          | *A. pinata*          | 66.7%       |
| *P. indicus*        | 91.6%                | VS          | *A. heterophylus*    | 58.3%       |
| *T. mantaly*        | 91.6%                | VS          | *D. Indica*          | 58.3%       |
| *M. elengi*         | 91.6%                | VS          | *M. indica*          | 58.3%       |
| *S. mahogony*       | 83.3%                | VS          | *M. champaca*        | 58.3%       |
| *B. purpurea*       | 83.3%                | VS          | *A. damara*          | 50%         |
| *C. papuana*        | 83.3%                | VS          | *R. regia*           | 41.7%       |
| *F. benjamina*      | 75%                  | S           | *S. grandiflora*     | 41.7%       |
| *L. speciosa*       | 75%                  | S           | *P. roebelini*       | 33.4%       |
| *C. petandra*       | 75%                  | S           | *V. Merilii*         | 33.4%       |

VS : very suitable  LS : Less Suitable  S : Suitable  NS : Not Suitable

Trees with a very suitable category have different physical characteristics, which has thin leaves, a large number of leaves, and a dense heading. Trees that have thin leaves also have good pollution absorbing ability. The more dense and the number of leaves, the more the amount of surface area of the leaves. This relates to the increasing number of stomata on the surface of the leaf so that more gas pollution volumes are absorbed. This is in accordance with the research conducted by Astra et al. [16] which states that the higher the density of stomata, the thinner the thickness of leaves and the smaller the weight of the leaf type then the higher the ability in absorbing gas NO2. In addition, the structure of vegetation is increasingly dense planting distance between trees in an green open spaces then green open spaces capability can perform the process of absorption against pollution that is better. According to research Carpenter et al. [17] the plant can reduce air pollutants through the process of oxygenation, which is the process of releasing oxygen into the atmosphere, and dilution, which is the mixing of polluted air with clean air.

The results of the analysis using the scoring method of the tree that very suitable because it has a flat deformed particle pollution that has the physical characteristics of a rough/furry/needle-shaped surface structure, has solid headers, has a bar texture and rough twigs, and dense twigs. The tree that belongs to the category is very suitable are *Diospyros blancoi*, *Lagerstomia speciosa*, and *Cupressus papuana*.

The criteria of the tree that can be snapped with particles well must have a rough, curved, feathery and tricoma leaf surface, the leaves are needle and also widened, solid and tight plant headers, stem skin texture and rough twig and the densities of the branches. The feathery and tricoma leaf surfaces are capable of snapped more particles than the hairless and tricoma leaf surfaces. Particles scattered in the air can stick to the fur and tricoma located on the surface of the leaf. According to Tambaru [18] characteristic leaves that can be used as reference in the selection of tree species for greening in the urban especially polluted location that is the surface of slippery leaves, shiny, coarse-feathered and wavy edges because it is able to absorb dust particles. The leaves that needle and widen more effectively in absorbing pollutants because it has a greater surface area of the leaf. Trees that have a vast period of headers and meetings can ensnare larger and more effective particles than the period of the open headers. In addition, rugged surfaces in stem structures and twigs also affect the tree’s ability to intercept...
particles. The density of the branches that are tightly on a tree is also more effective in snapped particles.

Table 4. Suitability of adsorbing particle pollution of selected plant species growing around green path of Bogor Botanical Garden Outer Ring-Road

| Plant species | Evaluation value (%) | Suitability | Plant species | Evaluation value (%) | Suitability |
|---------------|----------------------|-------------|---------------|----------------------|-------------|
| D. blancoi    | 90%                  | VS          | P. roebelinii | 65%                  | S           |
| L. speciosa   | 85%                  | VS          | M. elengi     | 65%                  | S           |
| C. papuana    | 81.5%                | VS          | A. heterophyllum | 65%               | S           |
| S. mahogany   | 80%                  | S           | T. mantaly    | 55%                  | S           |
| P. indicus    | 80%                  | S           | C. petandra   | 55%                  | S           |
| S. grandiflora| 80%                  | S           | D. regia      | 55%                  | S           |
| M. indica     | 75%                  | S           | A. damara     | 50%                  | LS          |
| B. purpurea   | 75%                  | S           | F. benjamina  | 50%                  | LS          |
| C. comunne    | 70%                  | S           | A. piata      | 45%                  | LS          |
| D. indica     | 70%                  | S           | R. regia      | 30%                  | LS          |
| M. champaca   | 65%                  | S           | V. merillii   | 30%                  | LS          |

VS: very suitable  LS: Less Suitable  S: Suitable  NS: Not Suitable

3.3 Air pollution tolerance index evaluation

This study show that all species have only two categor, which is intermediate and sensitive. Even just only two categories, each species has different biochemical amount, finding clearly indicate that the plants vary in their responses to similar air pollutants, and variation in air pollution tolerance may occur due to variation in any of the four biochemical parameters used to calculate the APTI. All data showed at Table 5 below.

Table 5. Biochemical properties of selected plant species growing around green path of Bogor Botanical Garden Outer Ring-Road

| Plant species                  | Ascorbat acid (mg/g) | Total Chlorophyll (mg/g) | pH | Relative water contain (%) | APTI | Evaluated response |
|-------------------------------|----------------------|--------------------------|----|---------------------------|------|-------------------|
| Ceiba petandra                | 4.00                 | 6.60                     | 6.54 | 87.33                     | 13.99 | Intermediate      |
| Veitchia merillii             | 4.00                 | 2.69                     | 6.02 | 97.02                     | 12.89 | Intermediate      |
| Minusoph elengi               | 3.99                 | 5.14                     | 5.73 | 84.62                     | 12.80 | Intermediate      |
| Lagerstomia speciosa          | 4.00                 | 3.19                     | 6.12 | 91.74                     | 12.66 | Intermediate      |
| Sutienia macrophylla          | 4.00                 | 3.70                     | 5.89 | 86.05                     | 12.44 | Intermediate      |
| Delonix regia                 | 4.00                 | 5.04                     | 5.89 | 80.39                     | 12.41 | Intermediate      |
| Artocarpus heterophillus      | 4.00                 | 3.98                     | 6.44 | 81.11                     | 12.28 | Intermediate      |
| Dillenia indica               | 4.00                 | 1.67                     | 5.44 | 92.90                     | 12.13 | Intermediate      |
| Diospyros blancoi             | 4.00                 | 2.10                     | 6.20 | 87.38                     | 12.06 | Intermediate      |
| Arenga piñata                 | 4.00                 | 6.59                     | 5.60 | 71.72                     | 12.05 | Intermediate      |
| Pterocarpus indicus           | 4.00                 | 5.14                     | 6.01 | 73.80                     | 11.84 | Sensitive         |
| Bauhinia purpurea             | 3.99                 | 3.91                     | 6.41 | 77.18                     | 11.83 | Sensitive         |
| Phoenix robelii               | 3.99                 | 2.02                     | 5.86 | 86.20                     | 11.76 | Sensitive         |
| Michelia champaca             | 4.00                 | 3.69                     | 6.12 | 76.82                     | 11.61 | Sensitive         |
| Canarium comunne              | 3.99                 | 2.80                     | 5.60 | 80.56                     | 11.41 | Sensitive         |
| Schoffiera grandiflora        | 4.00                 | 3.89                     | 6.26 | 66.29                     | 10.68 | Sensitive         |
| Terminalia mantaly            | 4.00                 | 4.22                     | 5.00 | 67.88                     | 10.48 | Sensitive         |
| Ficus benjamina               | 3.99                 | 2.02                     | 7.40 | 64.32                     | 10.19 | Sensitive         |
| Cupressus papyuana            | 4.00                 | 1.80                     | 5.16 | 69.84                     | 9.76  | Sensitive         |
| Magnifera indica              | 3.99                 | 2.50                     | 5.86 | 65.20                     | 9.70  | Sensitive         |
| Agathis damara                | 4.00                 | 2.12                     | 4.26 | 61.90                     | 8.74  | Sensitive         |
| Roystonea regia*              | -                    | -                        | -   | -                         | -     |                  |

* No measurements due to technical difficulties in leaf sampling
Based on the results of the research, the effect of air pollution on ascorbic acid content in plants tends to be the same in all species. The higher the ascorbic acid content then the plant is increasingly tolerant of air pollution. It is revealed that plants that are tolerant of air pollution have a high ascorbic acid content because ascorbic acid has functions as an antioxidant or a strong reductors that can prevent the occurrence of oxidation reactions. If the reaction of oxidation to take place the meal will form compounds that can poison plants. Reduced minerals, one of which ascorbic acid is one of the factors responsible for the formation of ROS (Reactive Oxygen Species). The ROS are very small reactive molecules that can cause damage to plant cell structures. Since ascorbic acid lowers the concentration of ROS in the leaves, ascorbic acid increases in the leaves will also increase the tolerance of the plant to air pollution.

The most high total chlorophyll content is *Ceiba pentandra* which is 6.60, while the lowest is *Dillenia indica* which is 1.67. The higher the content of chlorophyll in a plant then the more tolerant of such crops against air pollution. Higher chlorophyll content is thought to support plant tolerance to pollutants. The similar thing was presented by Carter and Knapp [19] who mentioned that pollutants can induce chlorophyll reduction. Air pollution may result in necrosis and chlorosis involving the mechanisms of chlorophyll damage.

The highest pH is found in *Ficus benjamina* which is 7.40 meaning weak base, while the lowest pH is found in *Agathis damara* which is 4.26. The content of the left pH value is known to increase tolerance to pollution. The degree of acidity of the leaves can be an indicator of crop tolerance because pH is instrumental in various plant physiology reactions.

The most substantial moisture content in *Veitchia merilii* is 97.02%, while the lowest is found in *Agathis damara* which is 61.90%. Air pollutants can increase the permeability of cells caused by the loss of water and the running of nutrients, resulting in fast leaves Senesence [20] so that plants that have relatively water content exposure to pollution will be more tolerant by pollutants.

The highest value of the APTI is *Ceiba Petandra* tree with a total of 13.99 whereas the lowest value is *Agathis Damara* with the amount of 8.74. Finding clearly indicate that the plants vary in their responses to similar air pollutants, and variation in air pollution tolerance may occur due to variation in any of the four biochemical parameters used to calculate the APTI. [14] Only two category found out in this area, those are intermediate and sensitive. Both are could be using as pollutants biomonitoring. Biomonitoring means

4. Conclusion
Results of the present study revealed that emission from high traffic urban area have substantial impact on the vegetation growing around Bogor Botanical Garden. The existence of the tree has fulfilled the physical criteria as absorbent and adsorbent pollution because it is dominated by very suitable and suitable category accordingly. Various biochemical parameters behaved differently in the studied plant species. All plant species could be used as pollutants biomonitoring.

References
[1] Hidayat, IW. 2008. Evaluasi jalur hijau jalan sebagai penyangga lingkungan sekitarnya dan keselamatan pengguna jalan bebas hambatan jagorawi [Tesis]. Program Pascasarjana, Institut Pertanian Bogor.
[2] Fakuara, Y. 1986. Hutan Kota: Peranan dan Permasalahannya. Bogor (ID): Departeman Manajemen Hutan. Fakultas Kehutanan, IPB.
[3] Nugrahan P, Nasrullah N, dan Sisworo EL. 2006. Risalah seminar ilmiah: Faktor Fisiologi Tanaman Tepi Jalan yang Menentukan Kemampuan Serapan Polusi Udara Gas 15 NO2. Bogor (ID): Program Pascasarjana Institut Pertanian Bogor.
[4] Dahlan, EN. 1989. Studi Kemampuan Tanaman Dalam Menjerap dan Menyerap Timbal Emisi dari Kendaraan Bermotor [Tesis]. Bogor (ID): Fakultas Pascasarjana, Institut Pertanian Bogor.
[5] Hermawan R, Kusmana C, Nasrullah N, dan Prasetyo LB. 2011. Jerapan Debu dan Partikel Timbal (Pb) oleh Daun Berdasarkan Letak Pohon dan Posisi Tajuk: Studikasus Jalur Hijau Acasia mangium, Jalan TOL Jagorawi. Media Konservasi Vol. 16, No. 3: 101-107.

[6] Liu, Y., Ding, H., 2008. Variation in air pollution tolerance index of plants near a steel factory: implications for landscape-plant species selection for industrial areas. WSEAS Trans. Environ. Dev. 4, 24–32.

[7] Arnon, D.I., 1949. Copper enzymes in isolated chloroplasts. Polyphenol oxidase in Beta vulgaris. Plant Physiol. 24, 1–15.

[8] Chouhan, A., Iqbal, S., Maheshwari, R.S., et al., 2012. A study of air pollution tolerance index of plants growing in Pithampur industrial area sector 1, 2 and 3. Res J Recent Sci 1, 172–177.

[9] Singh, S.K., Rao, D.N., 1983. Evaluation of plants for their tolerance to air pollution. In: Proceedings Symposium on Air Pollution Control, Indian Association for Air Pollution Control. 1. pp. 218–224.

[10] Noor, M.J., Sultana, S., Fatima, S., et al., 2014. Estimation of anticipated performance index and air pollution tolerance index and of vegetation around the marble industrial areas of Potwar region: bioindicators of plant pollution response. Environ. Geochem. Health 37 (3), 441–455.

[11] Ogunkunle, C.O., Suleiman, L.B., Oyedele, S., Awotoye, O.O., Fatoba, P.O., 2015. Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health. Agrofor. Syst. 89, 447–454.

[12] Chaudhary, S., Panwar, J., 2016. Evaluation of air pollution status and anticipated performance index of some tree species for green belt development in the holy city of Kurukshetra, India. Int. J. Innov. Res. Sci. Technol. 2, 260–277.

[13] Gholami, A., Mojiri, A., Amini, H., 2016. Investigation of the air pollution tolerance index (APTI) using some plant species in Ahvaz region. J. Anim. Plant Sci. 26, 475–480.

[14] Achakzai, K., Khalid, S., Adrees, M., Bibi, A., Ali, S., Nawaz, R., Rizwan, M., 2017. Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakistan. J. Environ. Manag. 190, 252–258.

[15] Suhandi R., B. Arief, dan A. Rahmah. 2017. Evaluasi Kinerja Jalan pada Penerapan Sistem Satu Arah di Kota Bogor. Bogor (ID). Program Studi Teknik Sipil, Universitas Paukan.

[16] Carpenter, PL, TD Walker, FO Lanphear. 1975. Plants in the Landscape. San Fransisco : W.H.Freeman and Company.

[17] Tambaru, E., 2012. Potensi Absorpsi Karbon Dioksida Pada Beberapa Jenis Pohon Hutan Kota di Kota Makassar, Pasca Sarjana Universitas Hasanuddin, Makassar.

[18] Tripathi A.K. dan Gautam M. 2007. Biochemical parameters of plants as indicators of air pollution. J Environmet Biol 28 (1): 127-132.

[19] Carter, G. and Knapp, A. (2001) Leaf Optical Properties in Higher Plants: Linking Spectral Characteristics to Stress and Chlorophyll Concentration. American Journal of Botany, 88, 677-684.

[20] Masuch, G., Kicinski, H. G., Kettrup, A. and Boss, K. S. (1988). Single and combined effects of continuous and discontinuous O3 and SO2 emission on Norway spruce needles. I. Histologic al and cytological changes. International Journal of Environmental Analytical Chemistry 32, 213-241.