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Jatropha integerrima, *Duranta erecta* and *Hibiscus rosa-sinensis* as Potential Lead Absorbent from Polluted Air in Dense Traffic Area

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Abstract: Lead (Pb) is one of the contaminants found in polluted air, especially in the area with dense traffic. Herbaceous plants are potentially used to reduce the Pb content in the polluted air. This study was designed to evaluate the potential of several plants, such as *Jatropha integerrima*, *Duranta erecta* and *Hibiscus rosa-sinensis*, as Pb absorbents from polluted air based on Pb accumulation and chlorophyll levels. The lead content was measured using atomic absorption spectrophotometry (AAS), while the chlorophyll content was tested using spectrophotometers at wavelengths of 649 nm and 665 nm. Results showed that the three plant species had potential as Pb absorbents from the air. The highest lead content was found from *J. integerrima* at 1.293 mg/kg, followed by *H. rosa-sinensis* at 1.232 mg/kg and *D. erecta* at 0.840 mg/kg. On the other hand, the highest level of leaf chlorophyll content was *H. rosa-sinensis* at 16.116 mg/kg, followed by *D. erecta* L. at 12.594 mg/kg and *J. integerrima* Jacq. of 10.297 mg/kg. No correlation was found between the Pb level and chlorophyll content of the three plants. It can be concluded that the three herbaceous plants have potential as Pb absorbents in the polluted air.

Key words: Phytoremediation, air pollutant, Pb, *Jatropha integerrima*, *Duranta erecta*, *Hibiscus rosa-sinensis.*

Introduction

Surabaya is one of the largest cities in Indonesia with rapid growth in traffic volumes. This causes traffic jams, which results in increasing air pollution. Result of a survey previously conducted on traffic performance of Surabaya in 2018 shows that many areas in the city experienced traffic jams at various levels; high, medium, and low. For example, the total traffic volume in Diponegoro street was 229,196 units of vehicles/day (high level of traffic), in Darmo street was 199,888 units of vehicles/day at (medium level), and in Dr. Ir. H. Soekarno street was 148,820 units of vehicles/day (low level) (Surabaya City Department of Transportation, 2015). The imbalance between the increasing number of vehicles and the available road facilities resulted in rising traffic, which affected air clarity. About 85% of air pollution occurred was caused by a high level of motorised vehicles activity. The normal lead level found in unpolluted air ranges from 0.0001 to 0.001 $\mu g/m^3$ (Kumaat, 2012), however, this level is increased along with the intensity of air pollution. According to WHO (2000), the threshold of Pb level allowed in environmental quality standards is 0.5-1.5 $\mu g/Nm^3$, while Indonesian Government Regulation number 41 of 1999 on Air Pollution Control establishes air Pb level at 2 mg/Nm^3 for 24 hours measurement and 1 mg/Nm^3 for 1 year measurement.

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One method that can be used to potentially ameliorate Pb from polluted air is by using plants as absorbents. Plants can be used as bioindicators of an ecosystem and adapt to their environment as indicated by changes on them, either morphological or physiological. As plants need carbon dioxide from the air to perform photosynthesis, increasing Pb level can affect the rate at which plants assimilate CO_2. In this case, a lot of effects can be observed from the leaf, as many contaminants diffuse to plant tissue through stomata via the molecular diffusion process (Sampson et al., 2003).

In recent years, phytoremediation starts to be developed and explored more as it is more affordable and efficient compared to other methods. Various phytoremediation agents can be used to manage pollution, for example, herbs, bushes, shrubs and trees. Several plants even can absorb heavy metals at a high level (Juhaeti et al., 2005). In several plant species, the Pb content normally ranges from 0.5 to 3.0 mg/kg (Ferdhiani et al., 2015). The source of air pollution from traffic is located at a height of 0–1 m, as many sources are forming tiny particles including friction between wheels and road and the smoke from the motor vehicles, thus shrubs which have a height of 0-1.5 m above ground level is potentially affected more through exposure (Mediastika, 2002).

Jatropha integerrima, or locally known as *Batavia* or *Jarak Pedas*, is an ornamental plant with morphological leaf features of green colours, round to oval shape, flat-curved edge, and rough surface due to trichomes. Its stem is reddish green, cylindrical shaped, while its flower has red colours and five petals (Asbani and Saptadi, 2020). *Duranta erecta* is a species of herb plant also mostly planted for ornamental purposes. It has morphological features of round-shaped green leaves with some yellow speck in the middle, which tends to be thin with jagged edges, slippery surfaces, and green stems. *Hibiscus rosa-sinensis* is also another ornamental plant with green leaf, sometimes with white patches, which has various shapes but generally are an oval shape with the pointy end, jagged edge, and smooth surface. The stems are commonly green to brown, while the flowers have various colours such as dark red, pink, orange, white and yellow (Ulfah et al., 2017). The three plant species have characteristics that can be used as bioindicators, especially in relation to absorbing Pb from polluted air.

Based on elaboration, this study was designed to evaluate the potential of *Jatropha integerrima, Duranta erecta* and *Hibiscus rosa-sinensis,* as Pb absorbent based on its Pb level and chlorophyll content in the leaf. This study can be used as a reference to reduce the amount of Pb in polluted air in dense traffic areas.

Methods

Leaf Sampling

This research was analytical observation research. Sampling was carried out in Diponegorostreet (Area A), Darmostreet (Area B) and Dr. Ir. H. Soekarno street (Area C) with varying traffic densities. Leaves sample was taken at the three locations for each street with three replications. Leaves taken were in the 5th node from the shoots. Every leaf sample was measured of its surface area using the AM350 leaf area meter.

Measurement of Chlorophyll Level

Leaf chlorophyll level was examined using spectrophotometers (MAPADA V-1100D, Shanghai Mapada Instruments Co., Ltd, Shanghai, Tiongkok) at wavelengths of 665 and 649 nm. The extract was made of each sample leaf. From each sample, 0.5 g of the leaf was macerated with 50 ml 96% alcohol until leaf colour dissolved. The solution was filtered with filter paper and chlorophyll level was examined from filtrate based on the level of optical density (OD). Level of chlorophyll *a*, chlorophyll *b*, and total chlorophyll were calculated using the Wintermans and de Mots formula [8]:

$$\text{Chlorophyll } a = 13.7 \times \text{OD } 665 - 5{,}76 \text{ OD } 649 \text{ (mg/l)}$$

$$\text{Chlorophyll } b = 25.8 \times \text{OD } 649 - 7{,}7 \text{ OD } 665 \text{ (mg/l)}$$

$$\text{Total chlorophyll} = 20.0 \times \text{OD } 649 + 6{,}1 \text{ OD } 665 \text{ (mg/l)}.$$

Measurement of Lead Content

The lead level in leaves was measured using atomic absorption spectrophotometry (AAS) (PerkinElmer Medtech, Waltham, Massachusetts, USA). Each sample leaf was weighed 2 g, then placed in a 800°C furnace for 3 hours. The sample was then added to 2 mL HNO_3 and 10 mL demineralised aqua. The solution was then filtered and its absorbance was analysed using AAS. The lead content was measured using the standardised Pb Level Test Method in Indonesian National Standard (SNI) No. 06-698945 of 2005. The following formula was used to calculate the Pb level:

$$Cy' = (Cy \times V/W) \times 1000$$

in which:

Cy' = lead (Pb) content in leaves (µg/g)

Cy = measured concentration (mg/L)

V = dilution volume (L)

W = leaf dry weight (g)

1000 = base conversion of mg to µg

Statistical Analysis

The leaf surface was analysed statistically using two-way ANOVA and continued with using Tukey post-hoc test. Data of Pb content and chlorophyll level was tested statistically to determine its correlation. Spearman test was used to determine the correlation of both parameters.

Results

Lead (Pb) Level in Leaf of the Three Plants Species

The lead content of *Jatropha integerrima, Duranta erecta*, and *Hibiscus rosa-sinensis* taken from three areas in Surabaya were found to be different as presented in Table 1. The highest level of Pb in *J.integerrima* was found from Area C at 1.516 mg/kg while *D.erecta* from Area B at 0.916 mg/kg and *Hibiscus rosa-sinensis* was also from Area B at 1.348 mg/g. The species with the highest Pb content was *J. integerrima* (Figure 1) at 1.293±0.345 mg/kg.

Chlorophyll Content in Leaf

The chlorophyll contents of *J. integerrima*, *D. erecta* and *H. rosa-sinensis* leaf were also found to be different, at 10.297 mg/kg, 12.594 mg/kg and 16.116 mg/kg, respectively (Figure 2). *Hibiscus rosa-sinensis* was found to have the highest chlorophyll levels compared to other species.

Table 1: Lead (Pb) content of each plant in three stations

Area	*Plant*	*Lead (Pb) content (ppm)*
A	*Jatropha integerrima*	1.121 ± 0.220
	Duranta erecta	0.731 ± 0.115
	Hibiscus rosa-sinensis	1.229 ± 0.116
B	*Jatropha integerrima*	1.243 ± 0.361
	Duranta erecta	0.916 ± 0.127
	Hibiscus rosa-sinensis	1.348 ± 0.153
C	*Jatropha integerrima*	1.516 ± 0.417
	Duranta erecta	0.875 ± 0.160
	Hiiscus rosa-sinensis	1.117 ± 0.196

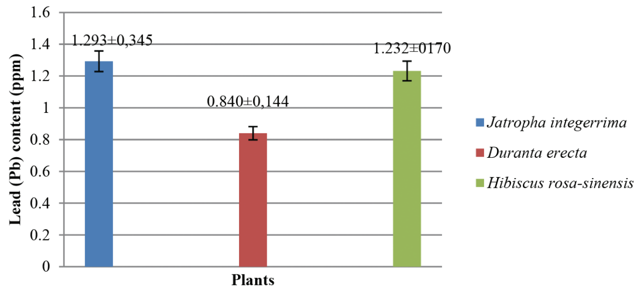

Figure 1: Lead content of *Jatropha integerrima*, *Duranta erecta* and *Hibiscus rosa-sinensis* from the three areas.

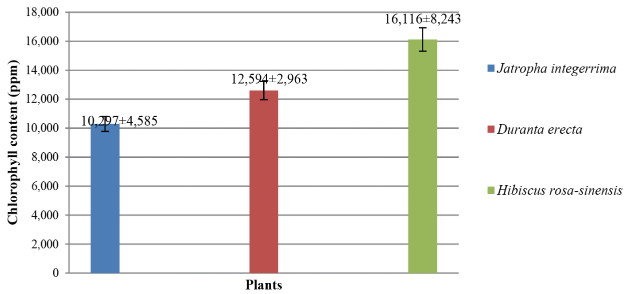

Figure 2: Chlorophyll content of *Jatropha integerrima*, *Duranta erecta* and *Hibiscus rosa-sinensis*.

Correlation of Lead Content to Chlorophyll Level

Based on a statistical test using Spearman correlation, the significance level of Pb to chlorophyll level was found to be at 0.438 ($p<0.05$). This indicated that there was no correlation between Pb and chlorophyll content.

Leaf Surface Area Measurement

Two ways analysis of variance (ANOVA) shows a significance level in all treatments less than 0.05 ($p <0.05$) so that significant difference was found on the treatment area (0.00), plant species (0.00), and the interaction between area and plant species (0.01) toward leaf surface area. Afterwards, the test continued using the Tukey test, the results show that there is a significant difference in Area A to Area B and C, but Area B is not significantly different from Area C. Meanwhile, there were significant differences in the treatment of various plant species, such as *Jatropha integerrima, Duranta erecta* and *Hibiscus rosa-sinensis* toward the leaf surface area.

Based on the results of measurement of leaf surface area, *J. integerrima* had the largest surface area compared to the other two species. On the other hand, based on location, leaves taken from area C with the lowest traffic density had the largest surface area compared to leaves from other areas (Table 2).

Table 2: Leaf surface area of three plants which absorb lead (Pb)

Area	*Plant*	*Average of leaf surface area (cm²)**
A	*Jatropha integerrima*	83.56 ± 11.75^{Ac}
	Duranta erecta	34.61 ± 4.39^{Aa}
	Hibiscus rosa-sinensis	57.82 ± 4.02^{Ab}
B	*Jatropha integerrima*	103.41 ± 4.90^{Bc}
	Duranta erecta	31.90 ± 10.76^{Ba}
	Hibiscus rosa-sinensis	89.22 ± 6.20^{Bb}
C	*Jatropha integerrima*	104.47 ± 10.63^{Bc}
	Duranta erecta	52.28 ± 7.70^{Ba}
	Hiiscus rosa-sinensis	87.05 ± 1.42^{Bb}

* Different capital letters indicate significant difference based on Tukey test (<0.05). The uppercase letter notation shows the area of plants, while the lowercase letter notation shows the plant species.

Discussion

Jatropha integerrima Jacq., *Duranta erecta* L. and *Hibiscus rosa-sinensis* L. plants were used in this research as they were potentially able to absorb Pb from polluted air in areas of dense traffic. The three locations in the current study were chosen based on level of traffic; Diponegorostreet (high traffic jam), Darmostreet (moderate traffic jam), and Dr.Ir.H.Soekarno street (low traffic jam) to show the difference of lead absorbance in areas with varying degree of traffic density.

There were differences in Pb accumulation of the three plant leaves found in each location (Table 1). The highest level of Pb was found in *Jatropha integerrima* leaves at Area C (1.516 ppm), while the lowest was found in *Duranta erecta* from Area A (0.731 ppm). The results showed that the plant with the best potential as lead absorbent (Pb) in the air was *Jatropha integerrima* (Figure 2). The ability of the *Jatropha integerrima* plant is supported by morphological aspects which have rough surface characteristics and hairy leaves. According to Hrotko et al. (2020), leaves with hairy characteristics on their surface have a high potential in accumulating lead (Pb) when compared to leaves that have slippery surfaces. Hairy on the leaf surface can make particles of lead (Pb) live and enter into cells via stomata. The process of attaching these particles can cause disruption of metabolism that occurs in cells (Carcamo et al., 2019). Leaves that have a hairy and rough surface usually have the potential to accumulate lead (Pb) in quite a high amount compared to leaves that have a hairless and smooth surface. Traffic density, number of stomata, leaf characteristics and trichomes are some of the factors that can affect the Pb absorbance. The level of absorption in pollution is related to the level of traffic density and distance from pollution sources (Cesaroni et al., 2013; Manik et al., 2015). Pb absorption that occurs above the vegetation and in the soil can increase caused by the high density of traffic and decrease due to the distance of the plant from the near of highway.

Lead (Pb) bioaccumulation on the leaves of plants in dense traffic areas will be higher (Jafarabad et al., 2013), however, we found that more Pb was absorbed in an area with low traffic. The majority of Pb accumulates on the leaf surface can be caused by the high volume of vehicles (Sawidis et al., 2011). Vehicles volume increases as same as the volume of the traffic, resulting in more emissions and air contaminants (Agustin & Hamidah, 2019). Several factors are affecting the Pb level in leaves, such as the duration of exposure, heavy metal content in the soil, the seasons, traffic density, physiology and morphology of plants and environmental factors (Siregar et al., 2020), also supported by a wide surface area of *Jatropha integerrima* leaves compared to the other plants. A higher surface of leaf supports higher effectiveness in accumulating pollutants compared to the lower surface (Sæbø et al., 2012).

Differences in Pb level in each plant occur because of the varying level of tolerance and the ability to accumulate heavy metals such as Pb, Cd, Ag, and Au (Babovic et al., 2010). Lead (Pb) level in *Jatropha integerrima* and two other plants did not exceed the limit of Pb toxicity to plants. In various types of plants, the Pb level normally ranges from 0.5-3.0 mg/L (Ferdhiani et al., 2015). While the maximum limit of the Pb level contained in the plant is 3.5 ppm with a toxicity limit up to 1,000 ppm (Hana et al., 2017). Lead level exceeding the limit will inhibit and disrupt plant physiological processes, one of which is the inhibition of chlorophyll biosynthesis (Bajguz, 2011; Saygidegeret al., 2004). An increase of Pb level in leaves causes a decrease in chlorophyll content. Air pollution causes the levels of chlorophyll a and b to decrease (Geeta and Namrata, 2014).

Based on the results of this research, the plant which had the highest chlorophyll content was *Hibiscus rosa-sinensis* (16.116 ± 8.243 mg/L). Chlorophyll content differs among various plant species because of genetic, light intensity, and others. Plants with hairy and rough leaf surfaces have lower photosynthesis levels. Leaves of *Hibiscus rosa-sinensis* and *Duranta erecta* have slippery surfaces, thus, the pollutant particles cannot directly be absorbed by the leaves and do not reduce the chlorophyll content. Normal chlorophyll content contained in leaves is around 9.0-21.0 mg/L (Ferdhiani et al., 2015). Chlorophyll content on *Jatropha integerrima*, *Duranta erecta*, and *Hibiscus rosa-sinensis* is in the normal range, which means no physiological responses were shown towards Pb accumulation. This is supported by the previous study when a plant does not show symptoms of damage after absorbing pollutants, it can be used as a phytoremediation agent (Rachmadiarti et al., 2019).

Based on the analysis, there was no correlation found between the Pb level in the leaf and the chlorophyll content of each species. This was different from the previous study's previous result that showed chlorophyll levels tend to decrease when lead (Pb) content increased (Sulistyowati et al., 2016). On the other hand, there was no significant difference in environmental factors between the three locations that could possibly affect the accumulation of Pb.

Plants can be used to degrade pollutants in the environment such as pesticides, polyaromatic, heavy metals, hydrocarbons, and leachate from landfill waste. Increased heavy metals occur in plants through a complex compound formation due to root exudate, where plant roots emit several organic acids such as fumarate, citric, phenolic and malic acids, inducing a decrease of pH in the area surrounding the roots. This causes the heavy metal ions and soluble compounds to be absorbed by the roots. Heavy metals that are absorbed by roots will be translocated to other parts of the plants, including the leaf (Liu et al., 2013).

Plants with this ability can be used in phytoremediation. Plants that can be used as an agent of phytoremediator ideally have a high tolerance level of contaminants, biomass productivity and high contamination absorption capacity (Tangahu et al., 2011). Shrubs plants can distribute the lead (Pb) content in the leaves optimally because lead is part of PM10 (particulate matter) which has a size of ≤10 (Muzayanah et al., 2016). Meanwhile, plants which can be a lead absorbent have special characteristics such as sticky and rough surface of leaves, smooth hair, serrated edges, scaly, and needle-shaped leaves (Santoso, 2013).

The three plants used in this research are shrubs which are widely planted in dense traffic areas in Surabaya and have characteristics as phytoremediation agents. Based on the potential of the three types of plants to accumulate lead (Pb) in the air and its effect on chlorophyll content, *Jatropha integerrima* was the most effective plant to be used to remediate the Pb content in polluted air.

Conclusion

The results showed that the three shrub plants had potential as Pb absorbents in the air. The highest Pb content in the leaf was found from *Jatropha integerrima* (1.293 ppm), while the highest chlorophyll content was found from *Hibiscus rosa-sinensis* L. (16.116 mg/L). There was no correlation between the Pb level and the chlorophyll content of the three plants. This study can be used as a reference to reduce the Pb air contamination by utilizing plants as a bioaccumulator in the area with high traffic density.

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