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The analysis of level of lead (Pb) on lichens as a bioindicator of air quality in Medan Industrial Area and Pinang Baris Integrated Terminal in Medan, Indonesia

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Abstract. This study aimed to investigate the diverse types of lichens in Medan Industrial Area and Pinang Baris Integrated Terminal in Medan. The study was conducted for five months, starting from May to September 2016. It was a descriptive study, with a purposive sampling method. The research results showed that there were differences found in the lichens diversity in the two research locations. While the diversity index values (H') in Medan Industrial Area (0.13904) was low, the diversity index values in Pinang Baris Integrated Terminal (1.00572) were categorized as a medium. In the two research locations, seven types of lichens were found, consisting of six genus. The distribution pattern of lichens in Pinang Baris Integrated Terminal was clumped with the highest value of 12,96 on the type of *Graphis scripta*. The three types of lichens found in Pinang Baris Integrated Terminal have a clumped distribution pattern with the highest value of 12.96 in *Graphis scripta*, while the other three types of lichens with a uniform distribution pattern 0.43 on the type of *Ochrolechia tartarea* and *Opegrapha atra*. The physical-chemical factors of the environmental condition which supported the growth and the development of lichens in Medan Industrial Area and Pinang Baris Integrated Terminal were the average temperature (30.75°C and 30°C), average humidity (75.75% and 73.25%), light intensity (371 J and 500 J), and wind speed (1.34 m/s and 2,1 m/s). The accumulated Pb had a very high in thallus *Ochrolechia tartarea* (26,96 mcg/gram). The correlation between Pb lichens and the traffic density showed that *Parmelia saxatilis* had a very high significant correlation, compared with the other types.

Keyword : Diversity, lichens, industrial area, and terminal

1. Introduction

Lichens are a combination of fungi and algae, thus morphologically and physiologically is a unity. The lichens body is called thallus, which vegetatively has similarities to algae and fungi. Lichens are known as pioneer plants which live epiphytically in the trees, above the ground, above the rocks. Lichens have various colors, such as white, grayish green, yellow, orange, brown, red, and black [1]; [2]. Lichens are a part of biodiversity which has not received much attention.

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Lichens in Indonesia consist of 40,000 types, but only a few researchers in Indonesia has focused their research on this topic. Thus, the opportunity to study lichens in Indonesia is potential for development. Facts displayed in the biology books show that only a few types are known. In addition to the types, the benefits of lichens have not also been reviewed much yet. The benefits of lichens are known as medicinal plants, food ingredients for animals, perfume-making materials, the determinant of the age of rocks, materials/preparations of staining, and others [3]. Lichens can also be used as a bioindicator of air pollution and can accumulate pollutants. This is because lichens are highly sensitive to air pollution. As lichens have been known for its sensitivity to the natural conditions of its surroundings, thus if there is pollution gas, lichens cannot grow and develop well [1].

One of the most dangerous sources of pollutants to living things is Lead (Pb). These metals enter the human body through the respiratory and the digestive systems. The largest contributor to Pb pollutions in the air is the transportation sector. Dahlan states that motor vehicles are the main source of Pb which pollute the air in urban areas [4]. It is estimated that about 60 to 70% of Pb particles in urban air derives from motor vehicles, and about 75% of Pb added to fuel oil will be emitted back into the atmosphere [5]. Lead (Pb) contained in the air can accumulate in the body tissue of living things, especially on the lichens thallus. Based on a number of reports, lichens thallus can accumulate Pb derived from motor vehicle exhaust emissions. The results of a study by Bargagli and colleagues showed that lichens were a good indicator of air pollution [6].

Based on Soedaryanto's research, he found three types of lichens in a relatively polluted area and seven types in a controlled area in Denpasar, Bali. The results of a study in Pekanbaru city found 20 types of lichens in areas with a high, medium, and low vehicle densities [7]. However, there has not been much research on lichens in Medan, thus it was an opportunity to conduct research in this city.

Therefore, based on the above description, it was necessary to conduct a research on "The Analysis of Macro Epified Lichens Population as a Bioindicator of Air Quality in Medan Industrial Area and Pinang Baris Integrated Terminal, Medan."

2. Materials

The number of stands of mahogany trees found was 10 trees. The extensive lichens were drawn and measured using plastic transparencies. Then, the lichens were scrapped from the surface of the tree bark. After *Parmeliaceae* thallus was being tested with spot test reagents KOH 10%, it would get a reaction K^+ from yellow to red. The measurement of the lead content used AAS (Atomic Absorption Spectrophotometry).

3. Methods

The research was conducted in Medan Industrial Area and Pinang Baris Integrated Terminal Medan. These locations were chosen based on purposive sampling with different air conditions. The method used was descriptive with explorative survey and inventory of lichens types in mahogany trees. The sampling technique used was "Transect Vertical" method up to one meter high. The first 50 cm was made as plot one, and the second 50 cm was made as plot two. The number of plots in the mahogany trees on the two locations was $10 \times 2 \times 2 = 40$ plots. Each type of lichens was collected for an identification and documentation purposes. The identification was performed using "Key to the Lichen genera of Bogor, Cibodas and Singapore" [8] as the reference. In addition, the reference book "Grasses, Ferns, Mosses & Lichen" [9]; reports, and records relating to lichens were also used. The observed parameters were morphological type of thallus based on macroscopic, microscopic, and the habitat characteristics. The physical-chemical conditions of the environment (temperature, humidity, light intensity, and wind velocity) were also measured. Then, we calculated the number of thallus, the percentage of presence, and the diversity index value using the formula of Shannon - Wiener [10]; while the distribution pattern of each type of lichens was measured using the formula of variance ratio with the middle value [11]; [12].

4. Results and discussion

4.1. Description of the research locations

Medan Industrial Area is located at Mabar Village, Medan Deli District with an area of 524 hectares. This area is divided with two highways from Medan to Belawan Port. The position is strategic because it is 8 kilometers away to Belawan Port, 35 kilometers away to Kuala Namu Airport, and 10 kilometers away to Medan downtown.

On the other hand, Pinang Baris Integrated Terminal is one of two integrated terminals for land transportation in Medan. This terminal specifically accommodates buses within and between provinces which enter from the west of Medan, such as buses from Nangroe Aceh Darussalam (NAD). The terminal is located at Sunggal Village, Medan Sunggal District, Medan. Pinang Baris Integrated Terminal consists of ± 4 ha (40,000 m²) area, and the number of buses and other public transportations which come in and out daily is 3540 units [13].

4.2. Type and index of lichen diversity in the research locations

The diversity obtained through the research in both research locations was drawn from the diversity of all plots withdrawal (20 plots) as it was considered to have represented the entire community of the two locations. The types and values of diversity index are shown in table 1 below.

Table 1. Types and diversity index of lichens in the research locations.

Name of Types	Type of Thallus	Location 1			Location 2		
		Σ Thallus	%	H'	Σ Thallus	%	H'
1. <i>Graphis scripta</i>	Crustose	0	0	0	172	67,98	0,26
2. <i>Opegrapha atra</i>	Crustose	0	0	0	6	2,37	0,09
3. <i>Ochrolechia tartarea</i>	Crustose	0	0	0	6	2,37	0,09
4. <i>Parmelia glabratula</i>	Foliose	62	96,88	0,031	0	0	0
5. <i>Parmelia saxatilis</i>	Foliose	2	3,13	0,11	45	17,79	0,31
6. <i>Pertusaria amara</i>	Foliose	0	0	0	3	1,19	0,05
7. <i>Solenospora candicans</i>	Crustose	0	0	0	21	8,30	0,21
Total of Thallus		64	-	0,14	253	-	1,01
Average of Thallus		32	-	-	36,14	-	-
Diversity		2	-	-	7	-	-

Description: Location 1 Medan Industrial Area; Location 2 Pinang Baris Integrated Terminal; H' =Diversity Index; (% K) = percentage of presence.

Based on the research that has been conducted in Medan Industrial Area and Pinang Baris Integrated Terminal, there were seven types of lichens on mahogany trees, with different proportions of diversity in each location. In Medan Industrial Area, two types of lichens found were *Parmelia glabratula* and *Parmelia saxatilis*, while in Pinang Baris Integrated Terminal, six types of lichens found were *Graphis scripta*, *Opegrapha atra*, *Ochrolechia tartarea*, *Parmelia saxatilis*, *Pertusaria amara*, and *Solenospora candicans*. The type of lichen appeared in both research locations was *Parmelia saxatilis*. The least appear lichens in both locations were *Parmelia saxatilis* and *Pertusaria amara*. The presence of *Parmelia saxatilis* in both locations indicates that it is a type of lichen which is resistant to air pollution. It might also indicate that the two locations are classified as polluted, because *Parmelia saxatilis* usually grows in the bark of the acidified tree because of the pollutants from air pollution [14]. However, *Parmelia saxatilis* is less sensitive to high sulfur dioxide pollutants.

The type of crustose thallus was relatively more in numbers compared with foliose, while the types of fruticose and squamulose were not found. Similar results were also found in Riau that the type of crustose thallus was more dominant than the type of foliose thallus [15]; [7]. These results illustrated that the type of crustose thallus could grow easily. The type of crustose thallus is the most resistant type of thallus compared to the other types of thallus [15]. This is because lichens with morphological

type of crustose thallus is protected from the potential for water loss by persisting on its substrate, given that this type has characteristics that would be attached firmly to the substrate. It is also the type of homoimerous thallus tissue, that is the state in which the alga is located around the hyphae. The crustose type has a thallus structure, such as a layer of crust which is firmly attached to the substrate. In the research locations, the lichens with the crustose type was found more in numbers than the foliose. The types of lichens found are shown in figure 1 below.

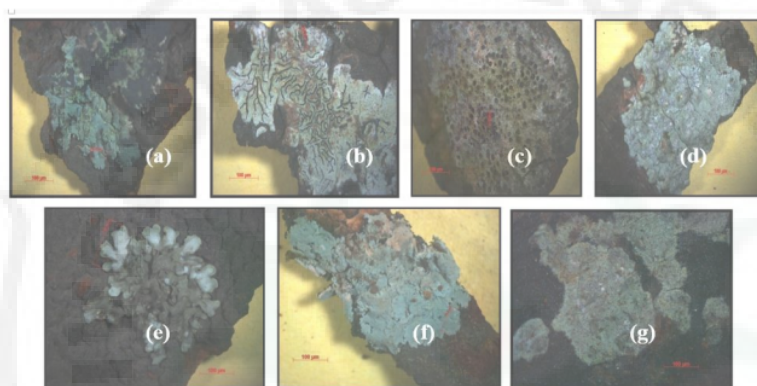


Figure 1. Morphology from a) *Parmelia glabratula*; b) *Graphis scripta*; c) *Opegrapha atra*; d) *Ochrolechia tartarea*; e) *Parmelia saxatili*; f) *Solenosphora candicans*; g) *Pertusaria amara*

The diversity index of the lichens in Medan Industrial Area with $H' = 0.13904$ was categorized as low because it was less than one, while the diversity index in Pinang Baris Integrated Terminal Medan with $H' = 1.00572$ was categorized as medium because the value was greater than one and less than two. The level of diversity may provide an idea about the maturity of the surrounding plant communities [16]. The lower the lichen diversity in both locations would indicate a lower organization within the community. Such conditions might arise as the result of ecological factors in both relatively polluted locations. This can be seen from the presence of many sources of pollutants around the research locations. For example, in Medan Industrial Area, there are at least ± 80 -100 motor vehicles passing every hour, and there are about 3-5 factories which flow the smoke into the air through the chimney around the research location. For Pinang Baris Integrated Terminal, there are ± 3540 units of motor vehicles which come in and out of the terminal. This is contrary to Panjaitan's opinion that the level of traffic density affects the lichen diversity found in the bark of the roadside trees of each observation location [7]. The lower the traffic density, then the diversity of lichen types found will be higher in the location. In this study, Pinang Baris Integrated Terminal had a higher traffic density than Medan Industrial Area, but Pinang Baris Integrated Terminal had a higher diversity of lichens than those in Medan Industrial Area. This could happen, as Istami said that it was because the industrial area has experienced an environmental change, such as air pollution, which allegedly because of the emissions derived from industry and transportation activities in the form of CO, SO₂, NO₂, and dust [17]. In the industrial area, these elements directly or indirectly cause some things that may constrain the growth, the development, and the existence of the lichens.

4.3. The distribution pattern of lichens in the Research locations

To determine the distribution pattern of each type of lichens in both research locations, the formula of variance ratio with criteria if $S^2 / \bar{X} = 1$: randomly distributed, >1 : clumped distribution; <1 : uniform distribution. The distribution pattern of lichens from the two research locations can be seen in table 2 below.

Table 2. Lichen distribution pattern in the research locations.

No	Name of Spesies	Location 1		Location 2	
		Variance	Distribution Pattern	Variance	Distribution Pattern
1	<i>Graphis scripta</i>	-	-	12,96	Clumped
2	<i>Opegrapha atra</i>	-	-	0,43	Uniform
3	<i>Ochrolechia tartarea</i>	-	-	0,43	Uniform
4	<i>Parmelia grabatula</i>	2,89	Clumped	-	-
5	<i>Parmelia saxatilis</i>	0,003	Uniform	3,39	Clumped
6	<i>Pertusaria amara</i>	-	-	0,2	Uniform
7	<i>Solenospora candicans</i>	-	-	1,58	Clumped

Description: Location 1 Medan Industrial Area; Location 2 Pinang Baris Integrated Terminal

The type of lichens found in Medan Industrial Area and Pinang Baris Integrated Terminal had a uniform and a clumped distribution pattern. The highest dispersion of lichens was *Graphis scripta* (12,96) which was found in Pinang Baris Integrated Terminal. Three types of lichens had a clumped distribution pattern and the other three types had the uniform distribution. The uniform distribution pattern was *Opegrapha atra* and *Ochrolechia tartarea* (0.43). The pattern of lichens was due to several supporting ecological factors, from the temperature, humidity, light intensity, and its relation to other factors which has not existed yet in the measured parameters but may also affect the distribution pattern of lichens. For example, rainfall, density of the parent tree, wind direction, and other factors.

4.4. Characteristics of the lichen habitat

The observation of the habitat characteristics or the physical-chemical conditions of the environment conducted in this study was by measuring the temperature, humidity, and light intensity. This measurement was performed only once for each study location. The physical-chemical conditions of the environment in the two research locations is shown in table 3.

Table 3. Physical-chemical condition of the environment in the research locations.

Environmental Factors	Location 1	Description	Location 2	Description
Temperature (°C)	30,75	Measured at 2.00 p.m	30	Measured at 2.00 p.m
Light Intensity (Joule)	371	Measured at 2.00 p.m	500	Measured at 2.00 p.m
Humidity (%)	75,75	Measured at 2.00 p.m	73,25	Measured at 2.00 p.m
Wind Velocity (m/s)	1,6	Measured at 2.00 p.m	2,1	Measured at 2.00 p.m

Description: Location 1 Medan Industrial Area; Location 2 Pinang Baris Integrated Terminal

Based on the measurement result, the average air humidity in both research locations were 75,75% and 73,25%. It supported the opinion of Noer [18] in Pratiwi [15] which stated that lichens preferred a dry place with humidity of 40% - 69%. Both locations had the average air humidity over that range. However, the average humidity in Pinang Baris Integrated Terminal was close to the range with 73.25%, thus the number of lichens growing in the area was more than those of Medan Industrial Area which had the average air humidity of 75.75%. The growth and the development of lichens in both locations was also influenced by the content of air pollutant. This opinion was strengthened by previous studies which argued that the level of pollution in the form of exhaust gas emission Pb would affect the abundance of the type of lichens, in which the closer to the highway, the less abundance of lichens will be found.

4.5. Lichens as a bioindicator of air pollution

Lichens are potential as a bioindicator of air pollution. The presence of lichens can be used as an estimator of pollution. Lichens are highly sensitive to air pollution, and have a wide geographical spread. Its sensitivity is often used as an indicator of air pollution in an area [19]. The research result showed a various number of thallus and the types of lichen which indicated the differences in tolerance levels of lichens to air pollution. According to Widjaya, the tolerant type of lichen is a type which is resistant to air pollution and is still able to live in polluted areas [20]. According to Negi and Beaven, the tolerant types can be used as an indicator of accumulation to detect levels of air pollutants [21]; [22].

The highest presence of lichens in this research was *Graphis scripta* with the highest number of thallus (172 thallus), followed by *Parmelia saxatilis* (45 thallus), and the least were *Pertusaria amara* with three thallus. *Graphis scripta* is geographically wide with the large number of thallus which is tolerant to pollution. Widjaya said that the ideal lichen as an indicator of pollution was geographically widespread [20]. This type of lichen indicates the uniqueness in the thallus forming a smooth, irregularly gray striped crust. *Graphis scripta* has crustose thallus type in the color of whitish-green, light green, and pale green, has a lateral long askocarp, and has a granula. Generally, askokarp has been found in a single and linear form. Askokarp with a transverse form on the septa, paraphyses are not branched. To differ the type of *Graphis scripta* and the other *Graphis sp.*, spot test reagents was performed by dripping 10% KOH solution on the surface of the thallus. Generally, *Graphis scripta* shows a negative reaction (K-) in yellowish brown after the 10% KOH is dripped, thus this type of lichen is easily recognized in the field. *Parmelia saxatilis* tends to be a tolerant bioindicator which has a foliose type with a loosely-attached thallus, pale gray, wide lobe, pseudocyphellae effigurate with a white medulla. *Parmelia saxatilis* can accumulate pollutants. The results showed that *Parmelia saxatilis* was resistant to pollutants with the highest number of thallus compared with the other foliose types. The foliose thallus type is a thallus which resembles a flat sheet, with its edge raised upward and curved like a leaf [17]. The characteristic of *Parmeliaceae* is that there is a pseudocyphellae covering the porous epicortex. Its medulla is white, and *Parmeliaceae* generally has salazinic acid. After the *Parmeliaceae* thallus was tested with spot test reagents KOH 10%, a K+ reaction yellow to red was obtained.

The results of lichens exploration in the two research locations indicated that there was a difference in the tolerance level of lichens to Pb metal accumulation. It is characterized by the difference in the types and the number of lichens found in each research location. Furthermore, the accumulation of Pb pollutants on the lichens thallus is shown in table 4.

Table 4. Lichens and accumulation of Pb metal in lichens thallus in the research locations.

No	Name of Spesies	Location 1		Location 2	
		∑ Thallus	Level of Lead (mcg/gram)	∑ Thallus	Level of Lead (mcg/gram)
1	<i>Graphis scripta</i>	-	-	172	2,34
2	<i>Opegrapha atra</i>	-	-	6	3,82
3	<i>Ochrolecia tartarea</i>	-	-	6	26,96
4	<i>Parmelia grabatula</i>	62	19,08	45	7,28
5	<i>Parmelia saxatilis</i>	2	27,15	3	5,19
6	<i>Pertusaria amara</i>	-	-	21	12,75
7	<i>Solenosphora candicans</i>	-	-	-	-

Description: Location 1 Medan Industrial Area; Location 2 Pinang Baris Integrated Terminal

Lead (Pb) can be accumulated on the surface of the plant organs or is absorbed into the tissues. A high concentration of lead in the plant tissue is caused by the entry process of lead into the tissues

which can be through several ways, such as: the absorption through the roots and the leaves. The absorption through roots occurs when Pb is in the form of a dissolved compound [23].

The accumulation power of Pb on each type of lichens is not the same. Therefore, certain types of lichens may have a high accumulation power. In this study, the highest accumulated Pb metal was found in *Ochrolechia tartarea* thallus with 26.96 mcg/gram, followed by *Solenospora candicans* with 26.96 mcg/gram and the smallest. The results showed that *Graphis scripta* had the largest number of thallus and the largest percentage of presence compared with the other types, but it did not have the highest Pb metal accumulation. According to Panjaitan and colleagues, the *Leprariaceae* family is characterized by the thallus which resembles flour, uneven spread, with margins forming small lobes from pale green to whitish yolks [17].

The correlation shown from the traffic density with Pb concentration on the lichens thallus was a positive correlation. Therefore, the higher the traffic density, then the concentration of Pb will be higher. Based on the statistical calculation with Pearson Product moment, the correlation with Pb obtained was $r = 0.11$ which indicated that the correlation was very low with the testing rules $t_{count} (0.28) \leq$ from the $t_{table} (1.895)$. Therefore, it can be said that there was no positive significant relationship between the traffic density of Pb content for each type of lichens. The correlation shown between the traffic density of each research location with the Pb concentration on each lichen thallus was as follows: *Ochrolechia tartarea* with $r = 0.63$, *Parmelia saxatilis* with $r = 0.94$, and *Buellia canescens* with $r = 0.9$. In the calculation of Product Moment Correlation, there were different correlation values for each type, in which some were highly correlated, and some were very highly correlated.

The increase of traffic density level is not accompanied by an increase in Pb accumulation on the lichens thallus. This can be influenced by various factors, one of which is the condition of the street. The condition of the narrow street in both locations may cause a high wind speed and a change in the distribution pattern of Pb. According to Rachmawati, the concentration of Pb particles will be decreased if the wind speed is high, thus that it will spread the Pb particles to a wider area [24]. Akhadi reaffirms that there are two main sources acting as air pollutants in the urban areas, namely moving sources (e.g. motor vehicles), and unmoving sources (e.g. industry and domestic) [25]. However, for big cities whose traffic are extremely dense, motor vehicles are the most dominant source of air pollutants. Congestion in every street segment will worsen the level of air pollution in urban areas. It can be used to determine the environmental quality which can be affected by the exhaust gas of each vehicle type.

5. Conclusions and Suggestions

5.1. Conclusion

In Medan Industrial Area, two types of lichens with a low diversity index ($H' = 0.14$) were found, while in Pinang Baris Integrated Terminal, six types of lichens with a medium diversity index ($H' = 1.01$) were also found. The crustose thallus type was more in numbers than the foliose type, while the type of fruticose and squamulose were not found in this study. The presence of *Parmelia saxatilis* type was found in both locations which had different ecological conditions. The least appeared lichen in both locations was *Parmelia saxatilis*, and *Pertussaria amara* was a type of lichen which was resistant to the air pollution. The types of lichens found in Medan Industrial Area had a clumped and a uniform distribution pattern. In Pinang Baris Integrated Terminal, three types of lichens had a clumped distribution pattern, while the other three types had a uniform distribution pattern. The physical-chemical conditions of the environment in Medan Industrial Area and Pinang Baris Integrated Terminal found were the average temperature 30,75°C and 30°C with average humidity 75,75% and 73,25%, light intensity 371 Jooule and 500 Joules, and wind speed 1.6 m/s and 2.1 m/s, respectively. The Lead Correlation (Pb) on each lichen thallus with the traffic density obtained was 0.11, positively significant. The highest correlation was in the type of *Parmelia saxatilis*, and the lowest correlation was *Graphis scripta*.

5.2. Suggestions

Further research on lichen as the bioindicator of air pollution should be conducted by measuring the accumulation of pollutants. The physical-chemical factors of the environment still need to be added to investigate other factors that may have a real effect on the presence of lichens, including rainfall, wind direction, altitude, soil pH, and tree bark pH.

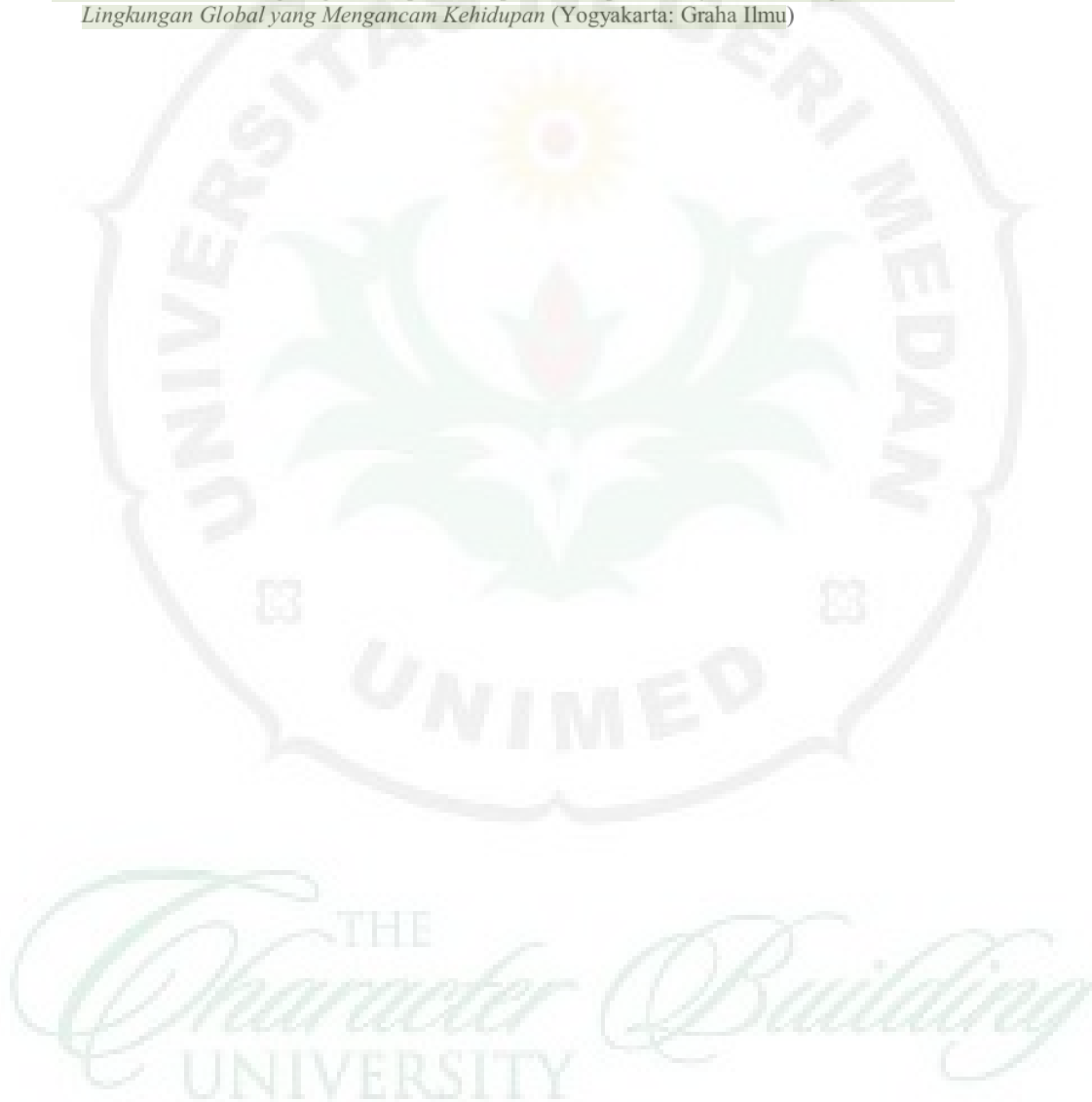
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