AL-KAUNIYAH: Jurnal Biologi, 17(2), 2024, 278-285
Website: http://journal.uinjkt.ac.id/index.php/kauniyah
P-ISSN: 1978-3736, E-ISSN: 2502-6720

THE UTILIZATION OF LICHEN AS BIOMONITORING NO_2 GAS EMISSION IN THE CITY OF PALEMBANG

PEMANFAATAN LICHEN SEBAGAI BIOMONITORING EMISI GAS NO_2 DI WILAYAH KOTA PALEMBANG

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Submitted: 4 September 2022; Revised: 20 July 2023; Accepted: 31 August 2023

Abstract

This study aims to determine the type of lichen as a bioindicator of air pollution and its potential in biomonitoring NO_2 gas emissions in the air using the index of atmospheric purity (IAP) calculation method. The research area was divided into 4 sampling stations. One location is a motorised traffic-free area designated as station 1. Station 2, 3, and station 4 are areas located on roads with different motorised traffic densities. At stations 1, 2, 3 and 4, NO_2 pollutant levels were measured following the SNI 19–7119.2–2005 procedure with the Griess Saltzman method. Furthermore, at the same station, the pollution level was also determined by calculating the IAP value. Based on the IAP value, the pollution level at the research area station is in the low-very high category with NO_2 gas pollution levels in the range of 7.95–12.1 µg/Nm^3/hour. There are 8 species of lichen whose presence can serve as bioindicators of NO_2 pollution in the air. These species are *Graphis* sp., *Lecanora* sp., *Lepraria* sp., *Dirinaria* sp., *Graphis scripta*, *Canoparmelia* sp., *Ochrolechia* sp., and *Lecidella elaeochroma*. The results of the average measurement of NO_2 levels show that NO_2 levels at the four sampling stations are still in a safe status because they are still below the air quality standards. The IAP value has a negative correlation with NO_2 levels in the air, where the higher the NO_2 levels in the air, the lower the IAP value, otherwise if the NO_2 levels in the air are lower, the IAP value will be higher. The Pearson Correlation test shows that there is a negative relationship (unidirectional relationship) between NO_2 levels in the air and IAP values. The higher the pollutants in an area, the lower the number of colonies and area of lichen cover on trees, especially in lichen species that are sensitive to air pollution.

Keywords: IAP; *Lichen*; NO_2

Abstrak

Penelitian ini bertujuan untuk mengetahui jenis lichen sebagai bioindikator pencemaran udara dan potensinya dalam biomonitoring emisi gas NO_2 di udara dengan metode perhitungan index of atmospheric purity (IAP). Area penelitian dibagi menjadi atas 4 stasiun sampling. Satu lokasi merupakan area bebas lintasan kendaraan bermotor yang ditetapkan sebagai stasiun 1. Stasiun 2, 3, dan stasiun 4 yaitu area yang berada pada ruas jalan dengan kepadatan lalu lintas kendaraan bermotor yang berbeda. Pada stasiun 1, 2, 3 dan 4 diukur kadar pencemar NO_2 mengikuti prosedur SNI 19–7119.2–2005 dengan metode Griess Saltzman. Selanjutnya, pada stasiun yang sama ditentukan pula tingkat pencemarannya dengan menghitung nilai IAP. Berdasarkan nilai IAP, tingkat pencemaran pada stasiun area penelitian berada pada kategori rendah-sangat tinggi dengan kadar pencemar gas NO_2 berada pada kisaran 7,95–12,1 µg/Nm^3/jam. Ada 8 jenis lichen yang kehadirannya dapat berfungsi sebagai bioindikator pencemaran NO_2 di udara. Jenis tersebut adalah Graphis sp, Lecanora sp., Lepraria sp., Dirinaria sp., Graphis scripta, Canoparmelia sp., Ochrolechia sp., dan Lecidella elaeochroma. Hasil pengukuran rata-rata kadar NO_2 menunjukkan bahwa kadar NO_2 di empat stasiun pengambilan sampel masih dalam status aman karena masih di bawah baku mutu udara. Nilai IAP memiliki korelasi negatif dengan kadar NO_2 di udara, dimana semakin tinggi kadar NO_2 di udara, maka nilai IAP akan semakin rendah, sebaliknya jika kadar NO_2 di udara semakin rendah, maka nilai IAP akan semakin tinggi. Melalui uji Korelasi Pearson, menunjukkan bahwa terdapat hubungan negatif (hubungan tidak searah) antara kadar NO_2 di udara dengan nilai IAP. Semakin tinggi polutan di suatu area, semakin rendah jumlah koloni dan luas penutupan lichen pada pohon, terutama pada jenis lichen yang sensitif terhadap polusi udara.

***Kata kunci**: IAP; Lichen; NO_2*

Permalink/DOI: http://dx.doi.org/10.15408/kauniyah.v17i2.27943

INTRODUCTION

Palembang is South Sumatra Province's capital with a 1.38% growth rate in 2010–2020. In line with the increase in the population growth rate, the transportation sector in Palembang also increases. Consequently, it increasing exhaust gases from vehicles, the main source of air pollution in urban areas. The pollutant from vehicles causes various respiratory problems both acute and chronic caused by primary pollutants such as dust particulate ($PM_{2,5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), dioxide sulfur (SO_2), carbon monoxide (CO), lead (Pb), and others (World Health Organization, 2011). There are number aspects coming up with the high levels of pollution and risks caused by vehicle gas emissions pollutants that entering the air makes air monitoring necessary. One of air quality monitoring techniques is biomonitoring by utilizing organism as indicators (Fandani, 2017).

Biomonitoring by utilizing plants as indicators is an alternative technique for more efficient air quality monitoring (Agnan et al., 2017). It can be done because vehicles exhaust gas emissions can interfere with the growth of plant such as plant structure, morphology, and biochemistry (Zulkifli, 2011) and one of organisms that can be used as air quality indicator is lichen. Lichen is very sensitive to air pollutants because it does not have a cuticle, so it absorbs the nutrition from the water and air directly.

The process happens when the pollutants absorbed into the thallus lichen tissues along with the process of absorption water and nutrition. Lichen cannot avoid the damage because lichen is not able to process and isolate the harmful pollutant rapidly (Brodo et al., 2001). Lichen does not have a mechanism for removing absorbed pollutants, so a change in the color of lichen thallus can identify pollutant accumulation (Ahmadjian et al., 1973).

The study about the relationship between pollutants and the growth of lichen had been carried out by Das et al. (2013) and the results showed that the number of lichen found in the research area had a direct relationship (positive correlation) with value of index of atmosphere purity (IAP). This article only focused on one of pollutant parts, NO_2. NO_2 is the primary pollutant that emitted from exhaust of motorized vehicles to human being health and environmental impact and it has been documented (National Expert Group on Transboundary Air Pollution (NEGTAP), 2001). NO_2 has been known as pollutant whose concentration is more than the quality standard of urban air (Driejana & Handika, 2013).

The aim of this study was to find out the type of lichen bioindicator of NO_2 gas pollutant and the potential use as a biomonitoring of NO_2 gas emission in the air by using the value calculation method index of atmosphere purity (IAP).

MATERIALS AND METHODS

The tools and materials that were used in this research consisted of plastic size 30 x 10 cm as material for making quadrant plots, tusk pin to stick the plot on the tree, tally *counter digital* to calculate motorised vehicle density, measuring tape 150 cm to measure the tree diameter, thermo-hygrometer to measure temperature and humidity, digital camera for photo documentations, macro lens with diameter 25 mm to focus the object of this research, and a set of laboratory tools called impinger to collect airborne contaminants by bubbling the sampled air at a high flow rate through a method specific asbsorbing liquid inside.

Before determining the sampling area station, a survey was carried on the feasibility of a number of areas and roads in Palembang which was used as sampling station. The targets of survey included the presence of lichen, environmental temperature and humidity, the density of motorised vehicles (vehicles per hours) in each sampling station. Based on the results of survey, station 1 was located on a conservation forest area and free of motorised vehicles. Then, station 2 was located on a road with a density of traffic 291.3 vehicles/hours, station 3 on a road with a density of traffic 379.3 vehicles/hours and station 4 on a road with a density of traffic 459.5 vehicles/hours. In this study, it was assumed that the higher the traffic density, the more NO_2 gas emissions are released in the air. Here is a description of each sampling station, station number 1= Nature uutilization area of

Punti Kayu Palembang; station number 2= D. I. Panjaitan street; station number 3= POM IX street; and station number 4= Gubernur H. A Bastari street.

The determination of the sampling tree was carried out by observing the presence of lichen colonies on the tree. The tree selected at each sampling station was determined according to the criteria of Agnan et al. (2017), (1) a woody tree with lichen, (2) it has a similar bark structure, (3) the tree is protected from damage, (4) the size of the trunk circumference >40cm. The circumference of the tree was calculated by measuring the tree using a 150 cm tape measure. Based on the observations, 5 sampling trees were selected at each station.

The Measurement of NO_2 Level

The measurement was carried out by taking the air sample by using the *passive sampler* method with a set of laboratory tools called impinger to collect airborne contaminants by bubbling the sampled air at a high flow rate through a method specific absorbing liquid inside. Then, the sample were analyzed spectrophotometrically about how to test nitrogen dioxide (NO_2) levels with Griess Saltzman method according to the SNI 19–7119.2–2005 procedure (Badan Standardisasi Nasional (BSN), 2005).

Lichen Data Collection

Lichen data collection on trees was carried out by placing four transparent plastic square plots that are placed at four different positions on the sample tree as high as ±1–1.5 meters from the ground (Agnan et al., 2017). The number of lichen species in the plot was counted and the area of colonies closure was measured. Lichen species identification was carried out by observing morphological characteristics such as color, shape, and type of thallus.

Lichen Identification

After the lichen data was collected, the data obtained were identified by using determination key on the website Lichen Determination Keys and the Ways of Enlichenment Lichen Photo Gallery.

Data Analysis

Data consisting of the number of lichens and the area of lichen colony cover were analysed to obtain data on the level of air pollution at each station by calculating the index of atmospheric purity (IAP) according to the formula of LeBlanc and De Sloover (1970) and the IAP criteria value of Conti and Checcetti (2001). Thus, the relationship between NO_2 levels in the air and IAP values and the presence of lichens can be determined. The IAP value can be calculated based on the following formula. $IAP = \sum_{1=i}^{n}(Q_i \times f_i)$ n= total number of species; f= frequency; Q= ecological index.

Table 1. Criteria of Index of Atmospheric Purity (IAP) (Conti & Checcetti, 2001)

IAP Level	Criteria	Description
A	$0 \leq IAP \leq 12.5$	Very high
B	$12.5 < IAP \leq 25$	High
C	$25 < IAP \leq 37.5$	Moderate
D	$37.5 < IAP \leq 50$	Low
E	$IAP > 50$	Very low

RESULTS

Based on observations, there were 10 types of lichen was found. At the research site, 8 types of *Crustose thallus* consisted of *Graphis* sp., *Canoparmelia* sp., *Ochrolechia* sp., *Lecanora* sp., *Lecidella* sp., *Arthonia* sp., and *Lepraria* sp. The types of *foliose thallus* consisted of *Dirinaria* sp. and *Canoparmelia* sp. The presence, number of species and coverage of each type of lichen were shown in Table 2, the distribution of each species in each station was shown in Figure 1.

Table 2. Presence, colony number, and closure area of lichen

Species	Presence per station area				Total colonies				Area of lichen closure (cm^2)			
	1	2	3	4	1	2	3	4	1	2	3	4
Dirinaria sp.	-	√	√	-	-	72	86	-	-	69	327.5	-
Graphis scripta	-	√	√	√	-	10	23	89	-	10	37	86
Graphis sp.	√	-	-	-	51	-	-	-	87	-	-	-
Canoparmelia sp.	-	√	√	√	-	127	37	11	-	130	40.5	9
Ochrolechia sp.	-	-	√	√	-	-	2	19	-	-	12	20
Lecanora sp.	√	-	-	-	76	-	-	-	53	-	-	-
Lepraria incana	-	√	-	√	-	42	-	29	-	40	-	57.5
Lepraria sp.	√	-	-	-	208	-	-	-	1,280	-	-	-
Arthonia sp.	-	√	-	√	-	87	-	2	-	90	-	2
Lecidella elaeochroma	√	√	√	√	31	12	12	5	18	11	4	5.5
10	4	6	5	6	366	350	160	155	1,438	350	421	180

Index of Atmospheric Purity (IAP)

Table 3 below, shows that the value of index of atmospheric purity (IAP) at station number 1 was included in level D or low pollution category, station number 2 was included in level C or moderate pollution category, station number 3 was included in level B or high pollution category, and station number 4 was included in level B or high pollution category. The difference of IAP value depended on the presence of the lichen species, the number of colonies, and the closure area of each lichen species. These pollution categories are adjusted to the pollution categories according to Conti and Cecchetti (2001).

Table 3. Index of atmospheric purity (IAP) at each sampling station

Station number	IAP value	Pollution level	Description
1	38.15	D	Low
2	25.71	C	Moderate
3	21.44	B	High
4	17.13	B	High

Pollution Level of NO_2 in the Air

Air sampling was carried out at one point for each station. The air sample was analyzed spectrophotometrically by using Griess Saltzman method. The analysis of NO_2 level referred to the SNI 19-7119.2-2005 (Badan Standardisasi Nasional (BSN), 2005). The result of NO_2 level analysis were shown in Table 4. Ambient air quality standard according to the government regulation Republic of Indonesia No. 22 year of 2021.

Table 4. Analysis result of NO_2 pollutant in the air at each sampling stations

Station	NO_2 level (µg/Nm^3/jam)		Mean	Description*
	(P_1)	(P_2)		
1	8.5	7.4	7.95	Fulfill of standard
2	9.1	7.7	8.4	Fulfill of standard
3	11.6	12.5	12.05	Fulfill of standard
4	9.2	10.6	9.9	Fulfill of standard
Maximum	11.6	12.5	12.05	Fulfill of standard
Minimum	8.5	7.4	7.95	Fulfill of standard

The correlation between NO_2 level and the value of IAP could be seen in Figure 1. NO_2 level and IAP value negative or un-directional relationship, it meant that the higher the NO_2 level the lower the IAP value was and vice versa. Similarly, the level of NO_2 and the number of lichen colonies also had negative or un-directional relationship, the higher NO_2 level the lower number of lichen colonies was, and vice versa (Figure 2).

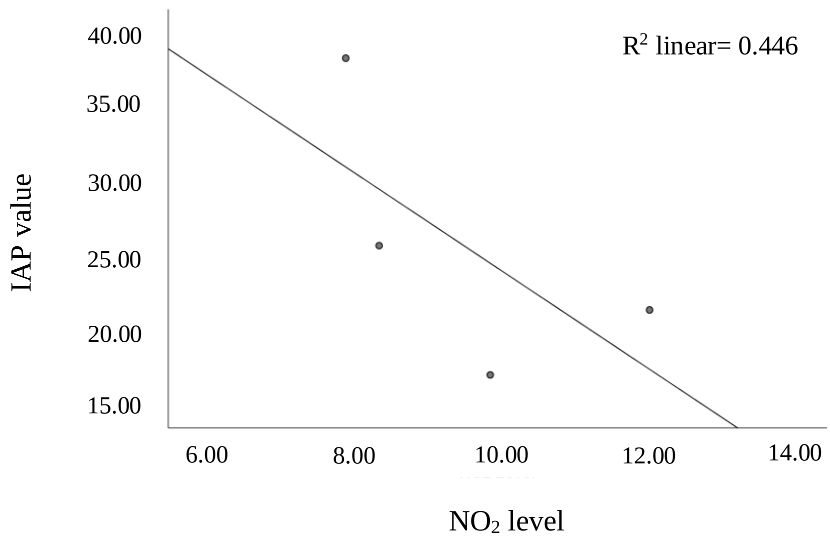

Figure 1. Correlation between the level of NO_2 to the IAP value

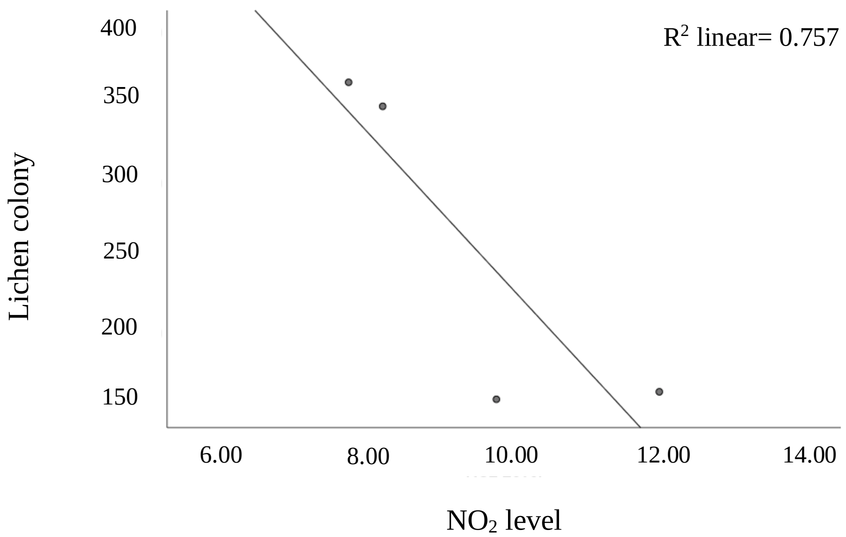

Figure 2. Correlation between the number of lichen colony to the NO_2 level

DISCUSSION

Observations on the presence of species, number of colonies and area of lichen cover at each sampling station were made in order to obtain lichen data to calculate the IAP value. Based on the observation, there were 10 types of epiphytic lichen found as can be seen in Table 2. The lichens found belonged to 7 tribes, namely *Calicaceae*, *Graphidaceae*, *Parmeliaceae*, *Ochrolechiaceae*, *Lecanoracea*, *Stereocaulaceae*, and *Arthoniaceae*, with a total number of colonies of 1,031. At each sampling station, 5 trees were selected according to the sampling tree selection criteria. Based on the survey results, many lichens were found attached to several types of trees including mahogany (*Swietenia mahagoni* (L.) Jacq.), ashoka (*Polyalthia longifolia* (Sonn.) Thwaites.), flamboyant (*Delonix regia* (Hook.) Raf.), king palm (*Roystonea regia* (Kunth.) O.F.Cook.), saga (*Adenanthera pavonina* (Linn.)), and pulai (*Alstonia scholaris* (L.) R.Br.).

Based on the type of talus, the types of lichen found and dominate the four sampling stations are lichen with crustose talus type which in order with the highest number of colonies, namely *Graphis* sp., *Canoparmelia* sp., *Ochrolechia* sp., *Lecanora* sp., *Lecidella* sp., *Arthonia* sp., and *Lepraria* sp. The lichen with foliose talus type found are *Dirinaria* sp. and *Canoparmelia* sp. Lichen species with crustose talus type were found at each sampling station with varying environmental abiotic factors. According to Boonpragob (2003), lichen with crustose talus type belongs to the tolerant talus type compared to other talus types. The results in this study show the amount of presence of crustose talus type lichen species at each sampling station. Lichen have different levels of sensitivity to pollutants, tolerant lichens will survive in environments with high levels of pollutants compared to sensitive species (Kuldeep & Prodyut, 2015).

The distribution of lichen species at each station can be seen in Table 2. Based on research conducted by Davies et al. (2006), *Lecidella* sp. is one of the lichen species whose sensitivity is at level 4 (scale: 1= tolerant, 10= sensitive). In accordance with this, the results of this study also show that *Arthonia* sp. is a species with sensitivity level 9. This is evidenced by the small presence of *Arthonia* sp. colonies at stations number 3 and number 4, where the values of NO_2 levels at both stations is higher than the other stations. While the presence of *Arthonia* sp. was quite abundant at station number 2 with a total of 87 colonies. Basically, lichen will passively absorb nitrogen and other particulates in the environment as nutrients to survive. However, if too many pollutants are absorbed, it will cause excessive growth or "over-fertilize", and can even cause death in some sensitive lichen species (Oliver et al., 2011).

The index of atmospheric purity (IAP) value is determined based on previously obtained lichen data in the form of species presence, number of colonies and lichen cover area. Station number 1 is an area with the lowest pollution level among the other three stations, station number 2 (moderate pollution level), station number 3 (high pollution level), and station number 4 (high pollution level). Differences in IAP values depend on the presence of species, number of colonies, and area of cover of each type of lichen (Table 2). IAP value has a positive correlation with the number of lichen colonies, where the higher the number of lichen colonies, the higher the IAP value, indicating that the pollution is still in the category of that the pollution is still in the low category.

The air quality measurement with NO_2 parameter was conducted during peak traffic hours with theair sampling frequency of two times with the analysis process in accordance with the procedures of SNI 19–7119.2–2005 About how to test NO_2 levels with the Griess-Saltzman method using spectrophotometry. Measurements were made by placing the impinger in an open field at a distance of ±500 m from the road body. The measured NO_2 levels are then compared with the air quality standards contained in Government Regulation of the Republic of Indonesia No. 22 Year 2021. The results of the analysis of NO_2 samples in the air can be seen in Table 4. Differences environmental factors at each sampling station may also can also affect the accumulation of pollutants in the air. Measurement of NO_2 levels in this study were measured under conditions of high temperature and humidity due to rain. According to Sánchez et al. (2002), high values of pollutant concentrations are due to low relative humidity and the absence of precipitation, the value of pollutant levels becomes low. Air temperature can also affect the accumulation of pollutants in the air, because the higher air temperature will cause the air to become tenuous and lower pollutants (Sari et al., 2013).

In addition to temperature and humidity, the direction of wind speed is also a factor that affects the differences in NO_2 levels in the air, as shown research by Çelik and Kadi (2007) which showed that pollutants can accumulate due to relatively slow wind speed, while few pollutants will accumulate due to relatively slow wind speed. While less pollutants will accumulate due to relatively fast wind speed.

Based on the previous explanation of IAP values and NO_2 levels, it can be known that IAP values have a negative correlation with NO_2 levels in the air which can be seen in Figure 1, where the higher the NO_2 levels in the air, the lower the IAP value. Seen from Pearson-Correlation test results, it can be seen that there is a negative relationship (unidirectional relationship) between NO_2 levels in the air and IAP values.

CONCLUSION

The calculation of *index of atmosphere purity* (IAP) value using lichen as a bioindicator was suitable as a method for determining the qualitative level of gas NO_2 pollution in the air. The IAP value had a negative relationship with NO_2 pollutant level in the air, but it had a positive relationship with the lichen presence. If the air in an area is polluted, it is possible that the number of colonies and the area of closure of lichen species will be increasingly especially for the species that are sensitive to air pollution.

This proved the assumption that the more gas emissions released into the air, the higher the level of air pollution. Meanwhile, the higher of pollutant in an area, the lower of number of colonies and the area of lichen coverage, especially in the type of lichen which is sensitive to air pollution. These results indicated that lichen can be a biomonitoring of NO_2 gas emission. The factor that affected lichen function as a bioindicator was the sensitivity of lichen to the presence of pollutant.

ACKNOWLEDGMENTS

The author would like to thank Department of Environmental and Cleanliness (DLHK) the city of Palembang, Conservation of Natural Resources Center of South Sumatra (BKSDA), and Biology Laboratory of Teacher Training and Education at Sriwijaya University for their assistance during the process of this research.

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