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Lichen Diversity, Substrate Preference and Environmental Dynamics as Indicators of Air Quality

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Abstract

This study assessed the lichen diversity, and substrate growth preferences in a bid to determine the air quality in Ikot Oyoro, Akwa Ibom State, Nigeria. A total of eight (8) lichen species were found in the survey area, the species includes; Candelaria concolor and Hypogymnia physodes which had the highest number of occurrences, while Phlyctic argena was the most common species found in the survey area throughout the survey period (May – July 2023). The rest of the species (Graphis scripta, Hyperphyscia adglutinata, Cladionia ochrochlora, Flavopermelia caperata and Cladonia ochrochlora)

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were found in at least two (2) trees. For May; Nitrogen-sensitive species found were 43, while Nitrogen-tolerant had 262. In June, N-sensitive (41) and N-tolerant (1966). July recorded N-sensitive (74) and N-tolerant (1803). Elaeis guinensis was the predominant tree in the study area and the growth substrate for the lichen species found. Substrate pH ranged from 3.83 – 5.98 (acidic) while $PM_{2.5}$ *ranged from 8.10 – 32.2 for the 3 months of the survey. Lichen Indicator Score (LIS) shows the level of pollution in the survey area and at the end of the study period, LIS for May was 27.00, 235.00 for June and 218.25 for July which is greater than 1.25 in the Nitrogen Air Quality Index (NAQI) chart showing that the area is very N-polluted. In this study, lichens were used as reliable indicators to trace air pollution and it could be useful to combat the increasing anthropogenic disturbances in the study area.*

Keywords: Air pollution, *Candelaria concolor, Elaeis guinensis, Graphis scripta,* Lichen

INTRODUCTION

Over recent decades, air quality has become an environmental problem worldwide due to industrial activities and road traffic globally because of evidence that they are associated with respiratory and cardiovascular diseases in humans (Godinho *et al.,* 2008). Emissions from traffic today are the main cause of poor air quality in cities. NO is the main polluting gas emitted, oxidized by ozone to yield NO_2. However, vehicles emit a cocktail of other pollutants including CO, CO_2, volatile organic compounds, polycyclic aromatic hydrocarbons, particulates and metals (Larsen *et al.,* 2007). Secondary pollutants include ozone and aerosols (Larsen *et al.,* 2007).

Atmospheric monitoring has been necessary to control air quality and reduce pollution sources (Stamenković *et al.,* 2010; Attanayaka and Wijeyaratne, 2013). Lichens are one of the most notable biological components in monitoring and indicating environmental quality, especially air pollution (Shukla *et al.,* 2012). Lichens are organisms formed by a symbiotic relationship between a fungus (mycobiont) and one or more photosynthetic partners, algae or cyanobacteria (photobiont). Also, some lichen species have been found to be associated with basidiomycete yeasts (Spribille *et al.,* 2016). Organisms such as lichens lack defensive tissues, so they can easily absorb water, nutrients, and gasses straight from the environment. Owing to these physiological peculiarities, lichens are vulnerable to several anthropogenic threats, such as air emissions, climate change, and forest management (Giordani, 2019). Lichens have been used as a biological indicator for air pollution since 1866, when epiphytic lichens were used to assess the air pollution in the local area (Nylander, 1866). Since then, lichens have been the most studied biological indicator (Boonpeng *et al.,* 2018) and have been defined as "permanent control systems" for air pollution assessment (Nimis, 1990).

The ability of lichens to absorb toxic materials such as sulphur dioxide (SO_2), fluorine (F_2) and nitrogen dioxide gas (NO_2) into the talus system for a long period of time has made the lichens a valuable indicator for air quality (Blett *et al.,* 2003). Lichen growth in the forest is influenced by various factors; amongst them are the availability of dead trees, the pH of the bark, air quality, relative humidity and exposure to sunlight (Coppins, 1984; Hawksworth and Hill, 1984). The fact that lichen biodiversity varies according to the quantity of air pollution in its surroundings makes lichen an ideal bio-monitor for assessing air (Winkler *et al.,* 2022). Furthermore, the widespread distribution and abundance of lichen in practically any environment makes it easier and more efficient to analyze the health of any ecosystem, including the urban ecology (Rosli and Zulkify, 2022).

Thus, this research was carried out to document lichen diversity, analyze the growth substrate and relate it to the air quality of Ikot Oyoro district of Akwa Ibom State, Nigeria. The study area is a busy commercial area and a stone throw from Eastern Obolo where crude oil exploration and associated activities such as gas flaring are carried out, thus justifying the need for the assessment of the air quality of this area.

MATERIALS AND METHODS

Study Area

This research was carried out for three months (May, June and July 2023) in Ikot Oyoro, Akwa Ibom State, Nigeria. Ikot Oyoro is close to Ikot Akpaden and Eastern Obolo, and its coordinates are 4°36’49N, 7°45’42E. It is also close to Eastern Obolo where a lot of industrial activities (e.g. crude oil exploration and associated activities such as gas flaring) take place.

Materials

Knife/chisel, envelopes, lichen survey sheet, beakers, filter paper, dry air oven, mortar and pestle and pH meter (model X00 3s465h3).

Collection and Identification of Lichen Samples

Nitrogen indicator (sensitive and tolerant) lichens and their characteristic features were first recorded. A 50 x 10 cm area on each of the three aspects of the tree (North, South and East) between 1.0 and 1.5 m above ground level was marked out for the survey. Recordings were restricted to lichens listed in the guide and included in the downloadable recording forms. The recording form was filled, adding a 1 (present) against each N-sensitive and N-tolerant taxa growing between 1m and 1.5m above ground level on each of the three aspects (North, South and East) within the 50 x 10cm area.

Preparation of Growth Substrate Sample

To test for the pH of the growth substrate, samples of the tree bark were taken from the parent plant secured inside a brown paper envelope and taken to the Botany laboratory, Akwa Ibom State University, Ikot Akpaden, Nigeria. Each sample was placed in an oven to dry and then ground to powdered form with a mortar and pestle, and each of the samples was poured into different containers and about 50ml of water was added to the samples and was left for 24 hours to mix, afterwards the sample was filtered using filter papers. After the sample was properly filtered, a pH meter (model X00 3s465h3) was used to test for the pH level and temperature of each sample and was recorded and each sample filtrate had different colours.

Sampling Site Parameter

AirVisual application was used to determine; the air quality index, $PM_{2.5}$, site altitude, Humidity and the temperate of the site. The GPS of the site was determined using a simple GPS application.

RESULTS AND DISCUSSION

The 3 months sampling of lichens from 8 trees in Ikot Oyoro revealed a total of eight (8) lichen species. It was recorded that the identified species belonged to seven (7) genera, grouped into 6 lichenic families (Table 1) (Figure 1-8).

Table 1: Genera and Family of Species Found in Ikot Oyoro

S/N	Lichen	Family	Genera
1.	*Phlyctic argena*	Phlyctidaceae	*Phlyctic*
2.	*Graphis scripta*	Graphidaceae	*Graphis*
3.	*Hyperphyscia adglutinata*	Physciaceae	*Hyperphyscia*
4.	*Cladonia ochrochlora*	Cladoniaceae	*Cladonia*
5.	*Flavopermelia caperata*	Parmeliaceae	*Flavopermelia*
6.	*Candelaria concolor*	Candelariaceae	*Candelaria*
7.	*Cladonia ochrochlora*	Cladoniaceae	*Cladonia*
8.	*Hypogymnia physodes*	Parmeliaceae	*Hypogymnia*

Lichen Biodiversity for the Month of May

In the study area, *Phlyctic argena* and *Graphis scripta* were the only N-sensitive species found and they recorded a total of 41 and 2 lichen counts respectively. *Hyperphyscia adglutinata* had the highest count with 174, *Cladonia ochrochlora* had the lowest count for N-tolerant species with 38 and *Flavopermelia caperata* count recorded was 50 for May (Table 2).

Lichen Indicator Score (LIS) for May

The average LIS score for Ikot Oyoro, was 27.00 with 5.75 for N-sensitive and 32.75 for N-tolerant species. Shows a relatively high shift and falls above the Nitrogen Air Quality Index of >1.25 which means the air quality in Ikot Oyoro region in the month of May is very N-polluted (Table 3).

Substrate, Environment and air quality data for May

Substrate, Environment and air quality data for the month of May recorded a maximum of 5.98 and 26.0°C and a minimum of 5.31 and 25.9°C Substrate pH and temperature. The temperature of the survey area was recorded at 29°C and the Humidity of the survey area was recorded at a maximum of 74% and 69% at minimum. Site altitude recorded a maximum of 38.6ma.s.l and a minimum of -2.6ma.s.l. The air quality index (AQI) recorded a minimum of 34 and a maximum of 46. $PM_{2.5}$ recorded a maximum of 11.1 and a minimum of 8.1 (Table 4).

Lichen Biodiversity for the Month of June

Phlyctic argena and *Graphis scripta* were still the only N-sensitive species found in the survey area in June with a total of 40 and 1 lichen count respectively. Other lichen species found included; *Candelaria concolor* with 1005 and *Hypogymnia physodes* with 396 species count. *Hyperphyscia adglutinata* had 217, *Cladonia ochrochlora* count recorded was 20 and *Flavopermelia caperata* had the lowest count for N-tolerant species with 16 for June (Table 5).

Table 2: Lichen Biodiversity for the Month of May (Ikot Oyoro)

Location									
Trunk	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	

Aspects	W	S	E	W	S	E	W	S	E	W	S	E	W	S	E	W	S	E	W	S	E	W	S	E	
N-sensitive lichen species																									
Phlyctic argena	0	4	1	5	4	8	2	1	1	1	0	0	0	2	2	1	2	1	0	5	0	0	0	1	41
Graphis scripta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2
																									Total
N-sensitive count per aspect																									43
N-tolerant																									
Hyperphyscia adglutinata	6	16	9	15	31	17	10	2	3	4	11	30	0	0	0	0	4	4	3	1	1	1	6	0	174
Cladonia ochrochlora	20	1	6	2	3	0	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	38
Flavopermelia caperata	0	0	0	12	10	18	0	0	0	0	0	0	0	0	0	1	9	0	0	0	0	0	0	0	50
																									Total
N-tolerant count per aspect																									262

Table 3: Lichen Indicator Score (LIS) Sheet (Ikot Oyoro): May

Location																									
Trunk	**Tree 1**			**Tree 2**			**Tree 3**			**Tree 4**			**Tree 5**			**Tree 6**			**Tree 7**			**Tree 8**			**Count**	**Average**
Aspects	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**		**Count/no. of trees**
N-sensitive	0	4	1	5	4	8	2	1	1	1	0	1	0	2	2	1	2	1	0	5	0	0	0	2	46	5.75
N-tolerant	26	17	15	29	44	35	11	2	6	5	11	30	0	0	0	1	13	4	3	1	1	1	6	1	262	32.75
	Lichen Indicator Score (LIS) = (Average N-sensitive) – (Average N-tolerant)																									27.00

Table 4: Substrate, Environment and air quality data: May

Tree	Lichen Growth Substrate	Family	Substrate	Colour of Substrate Extract	Substrate pH and Temperature	Temperature of Survey Area	Humidity of Survey Area	Site Altitude	Air quality index (AQI)	$PM_{2.5}$	GPS
1.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.98 26.0°C	30°	69%	-2.60	34	8.10	4°36′49 LAT 7°45′42 LON
2.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.80 25.8°C	30°	69%	18.30	46	11.10	4°36′50 LAT 7°45′42 LON
3.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.62 25.80°C	29°	74%	19.60	46	11.10	4°36′50 LAT 7°45′42 LON
4.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.62 25.9°C	29°	74%	21.50	46	11.10	4°36′50 LAT 7°45′43 LON
5.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.83 25.9°C	29°	74%	38.60	46	11.10	4°36′50 LAT 7°46′50 LON
6.	*Elaeis guineensis*	Arecaceae	Tree Bark	Gold	5.89 25.90°C	29°	74%	35.30	46	11.10	4°36′50 LAT 7°45′43 LON
7.	*Elaeis guineensis*	Arecaceae	Tree Bark	Rust	5.31 25.9°C	29°	74%	-13.00	46	11.10	4°36′50 LAT 7°45′42 LON
8.	*Elaeis guineensis*	Arecaceae	Tree Bark	Rust	5.7 25.90°C	29°	74%	19.50	46	11.10	4°36′47 LAT 7°45′41 LON

Lichen Indicator Score (LIS) for June

For the second month (June) of sampling, the average LIS score for the study area was 235.0 LIS with 5.125 and 240.125 for N-sensitive and N-tolerant respectively. Evaluating this parameter, it falls way above the Nitrogen Air Quality Index of >1.25 which means the air quality in Ikot Oyoro region in June is very N-polluted (Table 6).

Substrate, Environment and air quality data: June

Substrate, Environment and air quality data for June recorded a maximum of 5.53 and 25.5°C and a minimum of 4.47 and 25.5°C for substrate pH and temperature. The temperature of survey area was 24°C and the humidity of the survey area was 91%. Site altitude recorded a maximum of 51.4ma.s.l and a minimum of 44.7 ma.s.l. Air quality index (AQI) recorded 83. $PM_{2.5}$ recorded 27.2 (Table 7).

Lichen Biodiversity for July

No new lichen species were found, *Phlyctic argena* and *Graphis scripta* were still the only N-sensitive species found in the survey area in July, with *Phlyctic argena* having an increased number of counts (71) and *Graphis scripta* having 3 lichen count. *Candelaria concolor* had 836 and *Hypogymnia physodes* had 291 species count. *Hyperphyscia adglutinata* had a total of 263, *Cladonia ochrochlora* count recorded was 300 and *Flavopermelia caperata* had the lowest count for N-tolerant species with 74 for the month of July (Table 8).

Lichen Indicator Score (LIS) for July

The average LIS score for July was 218.25 for LIS with 9.375 for N-sensitive and 227.625 for N-tolerant. Nitrogen Air Quality Index of chart shows that the air quality in Ikot Oyoro region in July is very N-polluted because the LIS value falls above >1.25 (Table 9).

Substrate, Environment and air quality for July

Substrate, Environment and air quality data for July recorded a maximum of 4.39 and 25.8°C and a minimum of 3.82 and 25.8°C Substrate pH and temperature. The temperature of the survey area was recorded at 25°C and the Humidity of the survey area was recorded 89% at maximum and 87% on minimum. Site altitude recorded a maximum of 57.316 ma.s.l and a minimum of 38.946ma.s.l. The air quality index (AQI) recorded 93. $PM_{2.5}$ recorded 32.2 (Table 10 and 11).

Table 5: Lichen Biodiversity for June

Location																									
Trunk	**Tree 1**			**Tree 2**			**Tree 3**			**Tree 4**			**Tree 5**			**Tree 6**			**Tree 7**			**Tree 8**			
Aspects	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	
N-sensitive lichen species																									
Phlyctic argena	1	5	2	4	3	6	2	7	0	2	0	4	0	2	0	0	0	0	0	0	2	0	0	0	40
Graphis scripta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
																									Total
N-sensitive count per aspect																									**41**
N-tolerant																									
Hyperphyscia adglutinata	0	0	0	11	50	30	16	7	0	14	23	40	0	0	0	0	0	0	2	13	2	4	5	0	217
Cladonia ochrochlora	8	0	0	0	1	0	7	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
Flavopermelia caperata	1	0	1	0	1	11	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	16
Candelaria concolor	0	0	0	0	0	0	20	35	100	28	21	34	80	100	50	75	40	47	30	10	45	100	110	80	1005
Cladonia ochrochlora	0	0	0	0	0	0	13	13	95	0	5	0	0	56	56	7	5	12	10	15	25	0	0	0	312
Hypogymnia physodes	0	0	0	0	0	0	21	40	120	0	13	7	7	70	30	10	7	34	15	8	14	0	0	0	396
																									Total
N-tolerant count per aspect																									**1966**

Table 6: Lichen Indicator Score (LIS) Sheet: June

Location																										
Trunk	**Tree 1**			**Tree 2**			**Tree 3**			**Tree 4**			**Tree 5**			**Tree 6**			**Tree 7**			**Tree 8**			**Count**	**Average**
Aspects	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**		**Count/ no. of trees**

N-sensitive	1	5	2	4	3	6	2	7	0	2	0	4	0	2	0	0	0	0	1	0	2	0	0	0	41	5.125
N-tolerant	9	0	1	11	52	41	77	96	318	42	62	82	87	226	91	92	52	93	58	46	86	104	115	80	1921	240.125
	Lichen Indicator Score (LIS) = (Average N-sensitive) – (Average N-tolerant)																									235.0

Table 7: Substrate, Environment and air quality data: June

Tree	Lichen Growth Substrate	Family	Substrate	Colour of Substrate Extract	Substrate pH and Temperature	Temperature of Survey Area	Humidity of Survey Area	Site Altitude	Air quality index (AQI)	$PM_{2.5}$	GPS
1.	*Elaeis guineensis*	Arecaceae	Tree Bark	Burnt Umber	5.53 25.5°C	24°	91%	44.97	83	27.20	4°36′49 LAT 7°45′42 LON
2.	*Elaeis guineensis*	Arecaceae	Tree Bark	Burnt Umber	5.36 25.5°C	24°	91%	49.00	83	27.20	4°36′50 LAT 7°45′42 LON
3.	*Elaeis guineensis*	Arecaceae	Tree Bark	Burnt Umber	4.72 25.5°C	24°	91%	44.70	83	27.20	4°36′51 LAT 7°45′41 LON
4.	*Elaeis guineensis*	Arecaceae	Tree Bark	Bronze	5.15 25.5°C	24°	91%	38.60	83	27.20	4°36′50 LAT 7°45′41 LON
5.	*Elaeis guineensis*	Arecaceae	Tree Bark	Hickory	4.63 25.5°C	24°	91%	45.40	83	27.20	4°36′50 LAT 7°45′42 LON
6.	*Elaeis guineensis*	Arecaceae	Tree Bark	Tawny	4.49 25.5°C	24°	91%	48.60	83	27.20	4°36′50 LAT 7°45′42 LON
7.	*Elaeis guineensis*	Arecaceae	Tree Bark	Russet	4.47 25.5°C	24°	91%	51.40	83	27.20	4°36′50 LAT 7°45′43 LON
8.	*Elaeis guineensis*	Arecaceae	Tree Bark	Bronze	4.99 25.5°C	24°	91%	47.10	83	27.20	4°36′49 LAT 7°45′42 LON

Table 8: Lichen Biodiversity for July

Location																									
Trunk	**Tree 1**			**Tree 2**			**Tree 3**			**Tree 4**			**Tree 5**			**Tree 6**			**Tree 7**			**Tree 8**			
Aspects	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	
N-sensitive lichen species																									

Phlyctic argena	1	9	12	6	7	10	7	4	10	0	0	0	0	2	0	0	0	0	1	1	0	0	2	0	71
Graphis scripta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	3
																									Total
N-sensitive count per aspect																									74
N-tolerant																									
Hyperphyscia adglutinata	8	13	8	28	70	40	8	3	0	21	15	44	0	0	0	0	0	0	0	0	3	0	2	0	263
Cladonia ochrochlora	27	0	0	0	3	2	0	3	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	39
Flavopermelia caperata	1	0	0	7	4	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	74
Candelaria concolor	30	33	40	46	11	20	57	15	70	40	20	10	40	70	60	15	20	15	10	0	30	70	54	60	836
Cladonia ochrochlora	0	4	0	1	0	0	48	34	85	0	0	0	10	25	75	0	0	2	5	0	10	1	0	0	300
Hypogymnia physodes	0	3	0	0	0	0	39	12	90	0	0	0	10	20	87	0	0	20	5	0	5	0	0	0	291
																									Total
N-tolerant count per aspect																									1803

Table 9: Lichen Indicator Score (LIS) Sheet: July

Location																									
Trunk	**Tree 1**			**Tree 2**			**Tree 3**			**Tree 4**			**Tree 5**			**Tree 6**			**Tree 7**			**Tree 8**			**Count**	**Average**
Aspects	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**	**W**	**S**	**E**		**Count/no. of trees**
N-sensitive	1	9	12	6	7	10	7	4	10	0	0	0	0	2	0	0	0	0	2	2	1	0	2	0	75	9.375
N-tolerant	66	53	48	82	88	81	152	67	246	61	35	54	60	115	222	15	20	37	20	3	48	72	58	61	1821	227.625
	Lichen Indicator Score (LIS) = (Average N-sensitive) – (Average N-tolerant)																									218.25

Table 10: Substrate, Environment and air quality data: July

Tree	Lichen Growth Substrate	Family	Substrate	Colour of Substrate Extract	Substrate pH and Temperature	Temperature of Survey Area	Humidity of Survey Area	Site Altitude	Air quality index (AQI)	$PM_{2.5}$	GPS
1.	*Elaeis guineensis*	Arecaceae	Tree Bark	Tangerine	4.30 25.5°C	25° C	87%	57.31	93	32.20	4°36′50 LAT 7°45′42 LON
2.	*Elaeis guineensis*	Arecaceae	Tree Bark	Tangerine	4.11 25.5°C	25° C	87%	43.14	93	32.20	4°36′50 LAT 7°45′42 LON
3.	*Elaeis guineensis*	Arecaceae	Tree Bark	Tangerine	3.86 25.0°C	25° C	89%	52.08	93	32.20	4°36′50 LAT 7°45′43 LON
4.	*Elaeis guineensis*	Arecaceae	Tree Bark	Pale Orange	4.39 25.8°C	25° C	89%	44.75	93	32.20	4°36′50 LAT 7°45′43 LON
5.	*Elaeis guineensis*	Arecaceae	Tree Bark	Alloy	3.83 25.8°C	25° C	89%	38.94	93	32.20	4°36′50 LATS 7°45′42 LON
6.	*Elaeis guineensis*	Arecaceae	Tree Bark	Bright Orange	4.24 25.8°C	25° C	89%	51.92	93	32.20	4°36′50 LAT 7°45′42 LON
7.	*Elaeis guineensis*	Arecaceae	Tree Bark	Safron	3.82 25.8°C	25° C	89%	45.75	93	32.20	4°36′50 LAT 7°45′42 LON
8.	*Elaeis guineensis*	Arecaceae	Tree Bark	Bright Orange	4.36 25.8°C	25° C	89%	50.12	93	32.20	4°36′50 LAT 7°45′42 LON

Table 10: Nitrogen Air Quality Index (NAQI) Chart

LLichen Indicator Score (LIS) Scale	Meaning
0 – 0.5	Clean
0.5 – 0.85	At Risk
0.85 – 1.25	Nitrogen Polluted
>1.25	Very Nitrogen Polluted

Lichen Indicator Score (LIS) = Average Nitrogen Sensitive – Average Nitrogen Tolerant.

Fig. 1: *Hyperphyscia adglutinata*

Fig. 2: *Phlyctic argena*

Fig. 3: *Cladonia ochrochlora*

Fig. 4: *Graphis scripta*

Fig. 5: *Flavoparmelia caperata*

Fig. 6: *Candelaria concolor*

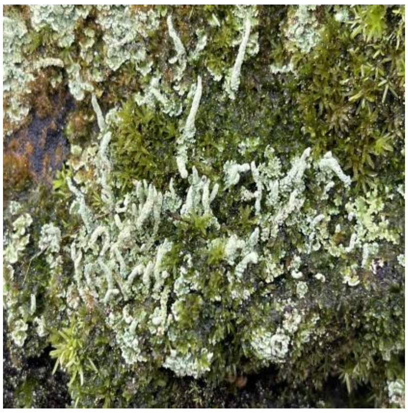

Fig. 7: *Cladonia ochrochlora*

Fig. 8: *Hypogymnia physodes*

DISCUSSION

The lichen indicator score (LIS), is one method that has historically been used to connect the distribution of lichen variety to the local air quality (Cioffi, 2009). The study area (Ikot Oyoro, Nigeria) may be categorized as having high levels of pollution due to its commercial operations and close proximity to Eastern Obolo where crude oil exploration and other industrial activities is are on-going. Ikot Oyoro region is now experiencing high levels of pollution because of these activities, but given the existing growth pattern, this situation could get worse over time. The study area is surrounded by lush vegetation such as secondary forests, grassy areas, etc, which gave it a high relative humidity. This study evaluated a wide range of variables, including relative humidity, substrate pH and temperature that may have an impact on the distribution of lichen species. Results indicated that the lichen growth substrate pH was all acidic. This is in line with the work of Öztürk and Oran (2011), who reported that the bark pH is a major factor affecting the settlement of epiphytic lichen species on a substrate. In their study, *Candelaria concolor* was observed in abundance in the study area as observed in this study as well.

Additionally, with less active circulation and less strong wind movements, these conditions contribute to increased relative humidity in this location. According to Golkar *et al.* (2020), relative humidity is closely related to the vegetation at this location. This is due to the production of oxygen from vegetative plants through photosynthesis, as well as plants such as trees and shrubs that provide shade to the area, helping to prevent water loss from the air through photosynthesis. In contrast, areas with high CO concentrations are densely populated with industrial and commercial buildings as well as paved roads (Zakaria *et al.*, 2020). This study also demonstrates that different variables have a major impact on lichen diversity. In this situation, the relative humidity and temperature of the environment have a significant impact on lichens. A high relative humidity percentage indicates that the surrounding air contains a lot of water. In addition, water plays an important role in the growth of many lichen species, which require a lot of water to survive. In the case where CO concentrations are high, the air will become more acidic. As a result, lichen species that cannot thrive in acidic conditions, especially fruticose and foliose lichens, will grow more slowly (Root *et al.*, 2021).

Temperature may influence the distribution of lichen species and the average temperature level of the survey area recorded was 29°C in May, 24°C in June and 25°C in July. With the mean temperature of the survey area being 26°C it shows the survey area is neutral according to temperature to pH dependence. According to Leh *et al.* (2020), although vehicle engines emit large amounts of pollution into the atmosphere, variables such as wind movement, temperature and humidity can minimize their effects.

CONCLUSION

This study indicates that lichen varieties may be utilised to monitor air quality in the environment. This study also reveals that certain factors, such as substrate pH, relative humidity and temperature have a considerable impact on lichen diversity in any given area. This study recorded eight (8) lichen species in Ikot Oyoro region, Nigeria. Furthermore, the air quality in Ikot Oyoro is classified as poor and very N polluted when compared to the lichen indicator score (LIS) and Nitrogen Air Quality Index (NAQI) chart. However, further studies need to be carried out to look into other intrinsic and environmental factors that may contribute to lichen availability in an area.

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