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Moss as Bio-indicator for Air Quality Monitoring at Different Air Quality Environment

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Abstract: ***Air quality monitoring by using bio-indicator currently being promoted and frequently used in studies due to their advantages compared to other scientific approaches. The advantages of using bio-indicator as a bio-monitoring in air quality are, it remains the cheapest, most available and simplest matrix for reliable atmospheric monitoring. This study was conducted to determine moss ability to be used as a bio-indicator for air quality monitoring when expose to different air quality environments. Four environmental conditions were chosen to conduct this study; urban area, reserve forest, living room and smoker's room. Leucobryum glaucum or Holland moss is used as the bio-indicator to monitor the air quality. Gridded containers of moss were left at each study location for the duration of two weeks. Physical observation was monitored weekly by examining colour changes of the moss. Survivability rate of the moss was determined by counting the numbers of grid where moss growth in each container. The data was recorded through physical observation of moss responses and survivability rate towards different air quality environment. The data was analyzed by using SPSS. Moss reacted accordingly towards different air quality environments. Moss reacts mostly at highly polluted environment, in smoker's room by changing from fresh green to brownish in color. In conclusion, moss can be used as a bio-indicator in air quality monitoring to determine air quality condition because moss changes its physical appearance and growth rate by the influenced of surrounding environment.***

Keywords: ***Air Quality Monitoring, Bio-Indicator, Moss, Urban, Smoker***

I. INTRODUCTION

Air is a substance that consists of odorless gaseous mainly made out of oxygen and nitrogen. It benefits the human health greatly in our daily life, but it may also cause a harmful effect toward the human health. This issue arises when the number of air pollutants disperses into the air increases, as for example, vehicles exhaust that produces carbon monoxides, tobacco smokes, factories that produce gaseous, open burning activities. Cutting the trees and building more skyscrapers does not help to improve the air quality condition. Despite, these activities contribute to worsen the air pollution, which already known on a very concerning level that affect the human health.

Responsibility of conducting air quality monitoring in Malaysia are being taken by the Air Division, Department of Environment (DOE), under the Ministry of Water, Land and Natural Resources. The indicator for the air quality status at any particular area is called as Air Pollutant Index (API). API is calculated based on five major air pollutants, which are sulfur dioxide (SO_2), nitrogen monoxide (NO_2), carbon monoxide (CO), particulate matter with diameter lesser than 10 micron (PM_{10}), and ground level ozone (O_3). The concentration of air pollutants are measured by 52 automatic air quality stations throughout Malaysia.

Air quality monitoring is important for controlling air quality that has led to many scientific development and approaches. The approaches in air sampling analysis that have been practiced are chemical and physical models. Invention such as monitoring devices helps to monitor air quality status in particular area. Air quality monitoring is important in order to maintain air quality levels as its Recommended Malaysia Air Quality level by Department of the Environment. However, there are some limitations identified such as time consuming for sampling and expensive cost for equipment [1]. Meanwhile, air quality bio-monitoring by using moss has been developed due to cost effective, a flexible monitoring time and a simple procedure [2].

According to AL-Alam, et al. (2019), bio-monitoring are proven to be efficient as a reliable passive environmental monitor of being available, accessible, inexpensive and non-toxic [3]. The main advantage of using moss is, the technique allows a multi-residue analysis of environmental pollutants that are able to accumulate several types of organic pollutants. Therefore, the assessment of harmful substances in the environment can be identified through biological monitoring. According to AL-Alam et al., (2019), the most advantageous matrices for environmental pollution bio-monitoring is the use of vegetation as it remains the cheapest, most available and simplest matrix for reliable atmospheric monitoring [3]. Vegetation that is frequently used are mosses, conifer and lichens for environmental pollution monitoring. In a study conducted by Bargagli, (2016), he concluded that moss and lichens account for the ruling vegetation under extreme alpine and polar conditions and are widely distributed all over the world [4]. Many surveys performed show the reliability of these organisms as the bio-monitors of atmospheric deposition on air pollutant. Thus, majority of researchers prioritizes moss as the bio-indicator due to its specialty, properties and advantages.

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Many studies used moss as the bio-indicator for air quality monitoring since 1960's due to the properties of moss characteristic and its ability to accumulates several types of air pollutants mainly heavy metals [2]–[4]. Compare to other vascular plant, moss are abundant and widely distribute as it has a special morphology structure and physiological features such as the accumulation of pigments. The accumulation of pigments is due to the absorption of water and ion through its whole surface as moss has no roots or ways in storing water internally. In general, moss is more suitable than endohydric species as bio-monitors at atmospheric pollutants [3]-[4].

Scholars have been using the biological indicator in air quality monitoring worldwide shows moss as a bio-indicator method as its simplicity, inexpensive and useful technique that provides informative atmospheric element deposition figures in terms of time and space [5]. Common elements such as water molecules (H_2O), carbon dioxide (CO_2), nitrogen gas (N_2) are absorbed by moss, and also metal elements such as lead (Pb), magnesium (Mg), uranium (U) and sources that come from anthropogenic factor. This just proved the effectiveness of moss accumulations and stored for a long time period [6].

Using moss as bio-indicator in air quality monitoring proved to have many benefits regardless the methodology used in the analysis procedure. Absorption on polycyclic aromatic hydrocarbon (PAHs), particulates matter (PM), metals and non-metals element has become one of the features of using moss as bio-indicator for air quality monitoring.

A study conducted by Leh et al., (2012), Kuala Lumpur has the highest pollution of O_3 and PM_{10} by the average number of days for unhealthy API for O_3 is 8.33% while PM_{10} is 1.39% from December 2008 to July 2009 [7]. In 2005, Kuala Lumpur reach a total number of 67 days of unhealthy AQI, 5 days in 2006 and 19 days of unhealthy API in 2007 [8].

Based on a study by Norela et al., in 2010, the average AQI sub-index for pollutants in botanical garden sampling stations was found to be within good AQI classification of 0-50 as the values recorded at the stations were 9, 12, 14 and 3 respectively. While for living room, the AQI was marked as unhealthy (101-200), and change to moderate (51-100) when the window is opened [9]. When the windows are closed the AQI gradually change back to unhealthy and the VOCs and CO_2 increased [10]. This suggests that the AQI reading of the living room is depended on the ventilation route of the room.

This study assessed moss reaction towards air pollutants at different air quality environments, by observing moss response and survivability rate. The study is conducted based on the following objectives:

A) General objective
To study about moss ability to be used as bio-indicator for air quality monitoring at four different air quality environments.

B) Specific objective
- To observe moss responses through physical appearance towards different air quality environment.
- To determine survivability of moss in urban area, forest reserve area, smoker's room and living room by observing the area of affected.

II. MATERIALS AND METHOD

A. Study Design

This study was conducted as an experimental, to determine moss ability to be used as a bio-indicator for air quality monitoring when expose to different air quality environments. This study evaluated air quality environment that would affect the most towards moss growth and development. Moss was placed at four different locations to represent different air quality environments. The first location was at the forest reserve, second location was at the urban area, third location was at a standard living room and lastly at smokers room. The response and growth survivability of moss at different air quality conditions was observed, recorded and analyzed during the study period.

B. Tested Plant

Leucobryum glaucum is the scientific name for Holland mosses that is also known as pincushion moss was used in this study. The moss was purchased from a local garden shop located in Putrajaya, Selangor during the initial stage of study. Holland moss is commonly used as an interior design material in creating green environment indoors and also in terrarium makings [11].

C. Study Location

To study about moss response, four different locations were chosen. Urban area, a reserve forest, a living room and a smoker's room as the study locations for period of two weeks. For the urban area, the moss was left next to a busy street nearby Jalan Sultan Ismail, Kuala Lumpur. For the reserve forest, the moss were left at a forest reserve area known as Pineapple Hill Forest Reserve, the only virgin tropical rainforest located in the heart of Kuala Lumpur. For the third location, a standard living room without smoker and lastly the moss was left at a smoker's room.

D. Experimental Set-up

- Moss container

The moss was set up in four different clear containers sizing 15 cm x 15 cm. Each container was labelled and contained a layer of pebbles rocks, a layer of garden mesh net for adding strength in upholding soil and rock structure, and finally the soil layer which provide nutrients to the moss. Exposure of air quality condition at study locations was done within two weeks of study period starting from 18th September 2019 until 2nd October 2019.

- Moss affected area in different air quality environments

The moss container was prepared with grid square measurement to record the data on moss affected area when exposed to air quality condition at respective study location. One grid measurement is equal to 1 cm x 1 cm that covered the moss surfaces inside the container. The grid counted was 10 grids x 10 grids, total area of the mosses inside the container is 225 cm².

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- Moss physical observation

The physical condition of moss was observed by the same method as previously described [11]. Appearance of moss response towards air quality at each study location is recorded after the 1st and 2nd week by using the grid squares for measurement. Moss physical appearance was observed through the area covered by moss in each container and whether the color of moss is changed after the exposure. Hence, moss areas that were affected by the exposure were recorded by using the measurement of grid square for respective moss container. The photos taken were kept as a form of results.

E. Statistical Analysis

The physical observation data through the area covered by moss was presented as figure. Mean and standard deviation were used to represent the area covered by moss.

III. RESULT

A. Physical Observation of Exposed Moss Towards Air Quality Environment

Physical observation was conducted to see the differences of moss physical condition prior to the exposure of air quality condition in study locations. The observation was taken in two phases; after the 1st week of exposure and after the 2nd week of exposure. Physical observation of the moss in each container for Week 1 and Week 2 of exposure are presented as in Table I.

Moss condition in each container before the exposure was in a healthy condition as the physical appearance show a very bright greenish color. But soon after the exposure on a particular study location shows an unhealthy form of moss. The moss color changes from greenish to yellowish, and to brownish color. A very obvious color changes observed in Container 1 and 4, which is the urban area and smoker's room. The moss color changed from greenish to yellowish in Week 1, and to brownish color in Week 2. On the other side, Container 2 (at forest reserve) moss appears to be healthier and lively compare to others, while Container 3 (at standard living room) with only a slight change in color after 2 weeks of exposure.

Table I: Moss physical observation in each study location

Study Location	Before exposure	Week 1 of exposure	Week 2 of exposure
Container 1 (busy street/urban area)			
Container 2 (forest reserve)			
Container 3 (standard living room)			
Container 4 (smoker's room)			

B. Moss Survivability Towards Different Air Quality Environment

The moss has been actively response to the air quality condition on the study location during the study period. The physical changes of the moss have been identified. There were changes in appearance of the moss color and some growth disruption. The changes conditions were defined into area of moss affected by counting the affected areas using a prepared grid in each container. Fig. I shows the area of moss that is affected by the air quality condition in each container. During the Week 1 of exposure, container 1 and 4 are the most affected compared to other containers. In week 2 of exposure, the highest affected areas are in Container 4 (smoker's room) with 8 grids, followed with Container 1 (urban area) with 7 grids, 2 grids for Container 3 (living room) and no moss affected area in Container 2 (forest reserve).

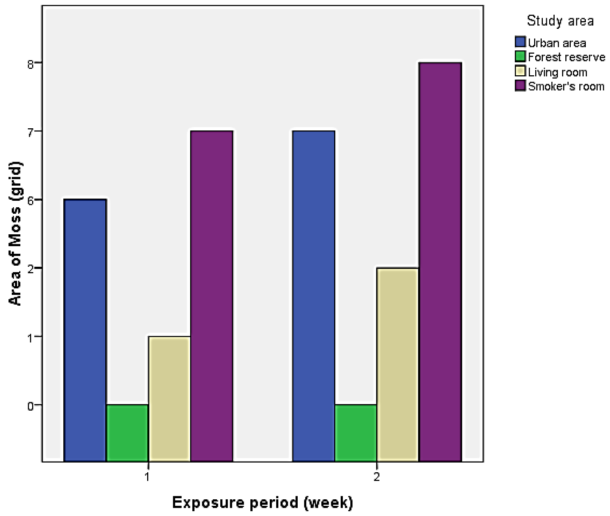

Figure I: Moss affected area (grid) in different air quality environments

C. Air Quality Environment That Affect Moss

Values of moss affected area exposed in different air quality environments were analyzed to determine the most significant contributor towards moss survivability. The result is shown in Table II. Mean and standard deviation of affected area for Container 1 (urban area) is 6.50 and 0.707, none affected for Container 2 (forest reserve), while Container 3 (living room) obtain 1.50 and 0.707 and the highest affected area in Container 4 (smoker's room) with 7.50 and 0.707. This concludes survivability rate of the moss depends on the air quality environment. Based on the result, Container 4 is exposed to a higher toxicity of air environment as compared other study locations.

Table II: Affected area affecting moss survivability[a]

pH value	Mean (±SD)
Smoker's room	7.50 (0.71)
Busy street/Urban area	6.50 (0.71)
Living room	1.50 (0.71)
Forest reserve area	0.00

[a]: Descriptive analysis
SD: standard deviation

IV. DISCUSSION

A. Moss Responses Towards Different Air Quality Environments

The moss showed changes in physical appearance after 1 week of exposure. Moss response is different according to the air quality environments that they are exposed to. Before the exposure, appearance of the moss color was in a healthier condition with more greenish color. After the first week of exposure, some of the container's mosses color turns from greenish color to a yellowish, and to brown color. An exception to container 2, there were no changes in appearance of the moss, as the moss in container 2 appears to become healthier compared to other containers.

A study by Mccauley et al., (2011), plant changes its physical appearance to indicate their health condition [12]. Nutrient deficiency or toxicity conditions are the main cause of the declining in the plant's health status. Excessive amounts of toxicity cause disruptions towards the plant growth and quality. Lacks of nutrient for plant growth can be described as nutrient deficiency. A plant shows its nutrient deficiency based on symptoms like growth retardation, chlorosis, interveinal chlorosis, purplish-red coloring and necrosis [12].

From this study observation of the physical assessment done towards the moss, several parts of the moss have been identified in color changes from greenish to yellowish and brownish color. Moss has endured chlorosis and necrosis. Chlorosis, define as a condition whereas the plant tissues change color into yellowish color indicating the chlorophyll reduction, while necrosis define as plant tissues death by turning brownish color.

B. Moss Survivability Towards Different Air Quality Exposure

Moss is affected by different exposure of air quality environment. In this study, the air quality condition in a smoker's room affect the most in moss survivability compared to the living room. This finding can be supported by the findings from [Pochodz & Dymu, (2018). They found that the moss samples that were exposed in a room where cigarettes have been smoked accumulated a higher concentration of heavy metals compared to the samples exposed in a smoke free room. But the smoker free room also shows an increase in elements indicated the movement of the air pollution through ventilation routes [13]. This proves the increasing of the area graph of the moss affected in the living room in week 2 of exposure.

According to Urošević et al., (2017), they found that the moss samples obtain low air pollution in a botanical garden that are surrounded with vegetation, concludes that the element concentrations were significantly lower compared to the streets close to botanical garden [14]. This has proved that the air pollution in forest reserve (Container 2) is significantly lower. The vegetation acts as a barrier against the pollution as compared to the urban area (Container 1) where sample is left beside a busy street.

V. CONCLUSION

From the findings, this study concluded that moss is suitable to be used as bio-indicator for air quality monitoring, as a passive monitoring. As a bio-indicator, moss could be used to determine the polluted environment in specific region that cause by pollution exposure. Moss is capable of changing its physical appearance that is influenced by the environmental factors such as acidic environmental condition [11].

The data of the study showed a different air quality environment affected the moss growth and physical appearance. Overall, the finding in this study support the research hypothesis that moss reacts according to the air quality environment where they are located. Moss survivability shortens when the surrounding environment is in high acidic condition. Moss responsiveness towards different air quality environment affected the moss physical appearance indicate the moss growth rate retardation. Bio-monitoring by using moss provides simplicity to conduct and less time consuming. Apart from that, moss also could be used in active monitoring where the location of experiment can be chosen according to the objectives of study.

A. Limitation of Study

Despite the positive result of this experimental observation study, there are some limitations encountered throughout the study. The moss species is an imported species that was adjusted to suit our environmental condition may influence the survivability of the moss towards our air quality environments. The study could obtain stronger evidence and results if air quality monitoring equipment can be provided. Finally, the weather and other condition in the surrounding area during the study period may affect the moss survivability.

B. Recommendation for Future Work

It is recommended for future studies to use a local moss type as the bio-indicator towards air quality monitoring as it can obtain a good result that suits our environmental condition. Equipment for air quality monitoring should be provided for more precise result. To produce precise result, longer period of exposure would be better to observe moss changes and adaptation to the environment. Chlorophyll extraction analysis before and after exposure, could be done to support the physical observation findings. Other than that, metal analysis on the moss extract could also be measured.

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