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Moss as Bio-indicator for Air Quality Monitoring

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Abstract*: Air quality monitoring nowadays has become a vital role to assess air quality level, to ensure the health of community are not affected with poor air quality. However, approaches for air quality monitoring either via physical or chemical assessment has built up some constraints. Time consuming, inaccuracy of data due to high maintenance of monitoring devices and only require competent person that able to conduct the monitoring. Therefore, the demand of using bio-indicator, such as moss, for air quality monitoring has risen due to multiple advantages. In this study, moss response and survivability rate towards acidic condition has been physically observed. The color changed and moss grid area were the parameters used to observe moss after acidic treatment. The moss, Leucobryum glaucum, was treated with artificial acid rain at three different pH; pH 3, 4 and 5. The moss was treated with 25 ml of artificial acid rain, once in two days for the duration of over 10 weeks; from week 4 until week 14 during the study period. The result showed that the moss mostly reacted towards lower pH of acid rain, at pH 3. The survivability rate of moss was decreasing when treated with pH 5 to pH 3. The physical observation which is determined by the area covered by moss (per square meter), showed that most of the area that covered by moss are affected at pH 3. The fresh green color that were observed before the artificial acid rain treatment has changed to yellowish color towards the 10 week of treatment. This study suggested that moss could be used by communities as a simple bio-indicator, to monitor air quality, especially for determination of acidic condition in certain area due to any surrounding factors.

***Keywords*: Air quality monitoring, bio-indicator, moss, acid rain.**

I. INTRODUCTION

Air space can be defined as a layer of atmosphere consist of many elements such as nitrogen, oxygen, argon and trace element [1]. The atmosphere layer itself plays crucial roles in maintaining the balance of ecosystem by protecting, supplying and providing basic needs of biological process of every single living organism [2]. The health and quality of air are being disrupted by pollutant substances that are suspended in the atmosphere which can harm both environmental and human health condition. The sources of air pollutants such as common air pollutants substance, metal elements, polycyclic aromatic hydrocarbon (PAHs) and radionuclides may pollute the air through natural activities (volcano eruptions, biological decay, forest fire, ultraviolet reaction, plants vegetation) and human activities (industrial activity, urbanization and transportation sector). It is very important to control the level of air pollutants in the atmosphere to avoid severe impacts especially on human health. The control can be done through measuring air pollutant levels by conducting air quality monitoring [3-6]. The importance of air quality monitoring has led to the development of many scientific approaches and development of chemical and physical model for air samples analysis. Stationary monitoring station, remote monitoring and biological assessment are some of approaches that have been used in conducting air quality monitoring. The invention of air monitoring devices also helps to monitor air quality [3,7]. Air quality monitoring is a crucial part for assessing air quality levels. However, some limitations have been identified in air monitoring such as time consume for sampling, inaccuracy of devices measurement reading, no standardize of monitoring process and expensive cost for air monitoring devices [7]. Assessing air quality by bio-monitoring using moss is currently being developed by environmentalist researchers. The advantages of using moss are low cost, flexi monitoring time and relatively simple procedure to conduct [8]. The usage of moss as bio-indicator in air quality monitoring has become extensively and rapidly developing among scholars worldwide due to the moss feature and specialty towards the environmental agents [4]. Moss are proven as effective in absorbing not only common elements such as water molecules (H_2O), carbon dioxide (CO_2), nitrogen gas (N_2) but also able in accumulating metals element such as lead (Pb), magnesium (Mg), uranium (U) and other pollutant sources that come from anthropogenic factor. The pollutants absorbed are stored by moss for a certain long period [9] after the exposure. Apart from that, the consequences of moss becoming an option among classical air monitoring through moss bag technique has risen where it is used to indicate air quality issues, and parameters such as emitting radiation concentration in atmospheric indicator, detection and measurement of pollution element in the air of specific region. In addition, moss has been used as indicator in Balkan region for contamination of uranium in atmospheric space that cause by military [10]. Improvement of moss bag technique in standardizing the procedure still need an improvement as to improvise result obtained for the monitoring [11] (Ares et al., 2014).

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Most researches have used moss bag technique to analyse metals elements content by doing chemical analysis such as saturation remanent magnetization (SIRM) analysis, Ethylenediaminetetraacetic acid (EDTA) extraction, with the usage of high specification of instrumentation such as X-ray spectrometer and graphite furnace atomic absorption spectrophotometry (Ares et al., 2014). 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 [12].

Most researchers used moss efficiency as bio-indicator towards heavy metals element, and used advance technology devices for statistical and chemical analysis. However, there are lack of researches that studied the relationship between moss activity and acid rain precipitation exposure that has been conducted.

Acid rain is normally measured in pH range between 4.3 to 5.5. Some of major pollutants that contribute directly in causing acid rain are volatile organic compound (VOCs), ammonia (NH_3), sulphur oxide (SO_x) and nitrogen oxide (NO_x) [13]. These compounds will be converted into acidic molecules such as sulphuric acid (H_2SO_4), nitric acid (HNO_3) and particles of ammonium salts (NH_4^+). The pollutants will then react with atmospheric water droplets forming acid rain precipitation, where the effects toward human and environmental aspects are much more severe [14].

For Malaysia, specifically in Klang Valley region; the centre for urbanization and heavy-light industrial activities, has been identified as one of area in Southern Asia region that are predicted to have more acid rain fall with pH ranging between 4 to 5 and extensive acidic atmospheric pollutants [15]. The researchers also stated that acid rain formation in Malaysia is caused by NO_x and SO_2 as the pollutants came from anthropogenic deposition. Apart from that, NH_3 can disrupt other acidic pollutants that causes more serious environmental damage and has negative effect of human health [16]. This study assessed moss reaction towards air pollutants through artificial acid rain exposure, by observing the moss response and survivability rate. The study conducted is based on the following objectives:

A) General objective

To determine moss ability to be used as bio-indicator for air quality monitoring in acidic environment.

B) Specific objective

- To observe moss responses through physical appearance towards artificial acid rain exposure.
- To determine the survivability of moss towards different pH of artificial acid rain exposure by observing the area of affected.
- To determine pH of artificial acid rain that affected the most on moss growth.

II. MATERIALS AND METHOD

A. Study Design

The study was conducted as an experimental, to evaluate moss responses and survival rate towards different pH of artificial acid rain. The study will also to determine the pH of artificial acid rain that will affect moss growth and development at the most. Moss was treated with acid solution at different pH through simulation of acid rain in a fixed timeframe. The growth, development and response of moss towards the artificial acid rain exposure condition was observed, recorded and analysed throughout the study period.

B. Tested Plant

Holland moss (*Leucobryum glaucum*) or also known as pincushion moss are used in this study, purchased from local garden shop located in Shah Alam, Selangor. This Holland moss are commonly being used as interior design planting materials in creating a green environment in buildings, and as main moss plants in making terrarium.

C. Artificial Acid Rain

Three pH values of artificial acid rain were prepared by mixing nitric acid (HNO_3) and sulphuric acid (H_2SO_4) at 1:2 molar ratio based on Lal & Singh, (2017), and diluted with distilled water. The three pH; 3.0, 4.0 and 5.0 were prepared by mixing 25 ml of HNO_3 (R&M Chemicals) with 50 ml of H_2SO_4 (Emsure®) initially, adjusted with distilled water, and the pH were determined by using pH meter.

D. Experimental Set-up

- Moss container

Three clear plastic containers (20 cm x 24 cm), gridded individually (1.5 cm x 1.5 cm), were labelled for respective pH of artificial acid rain. The grid covered all area of moss inside the container. Full area that covered with moss counted in the container was 10 grids x 14 grids of grid square that was 315 cm^2. Each container consisted three layers; pebbles rocks, garden mesh nets and soils to provide moss natural environment for their growth stimulation and to provide nutrients.

- Treatment of artificial acid rain

The exposure of simulated acid rain towards moss was performed within 10 weeks. For each moss container, the moss was treated with respective pH individually; container 1 treated with pH 5, container 2 treated with pH 4 and container 3 treated with pH 3 of artificial acid rain. In the early stage, the moss was treated with 25 ml of artificial acid rain for two times in a week. The physical observation for each treatment on respective container was performed at the end of each week. On the third week and onwards, the treatment of simulated acid rain towards moss was performed once in two days until the end of the study.

- Moss observation

Observation on physical appearance of moss was done after each artificial acid rain treatment. The moss physical appearance was observed through the area covered by moss in each container and whether the color of mass is changed after the treatment. As the treatment of artificial acid rain exposure began, moss showed the response. Hence, moss area that were affected by the acid rain was recorded using the measurement of grid square for respective moss container. The photos taken was kept as a form of results.

E. Statistical Analysis

The physical observation data through the area covered by moss was presented as figure.

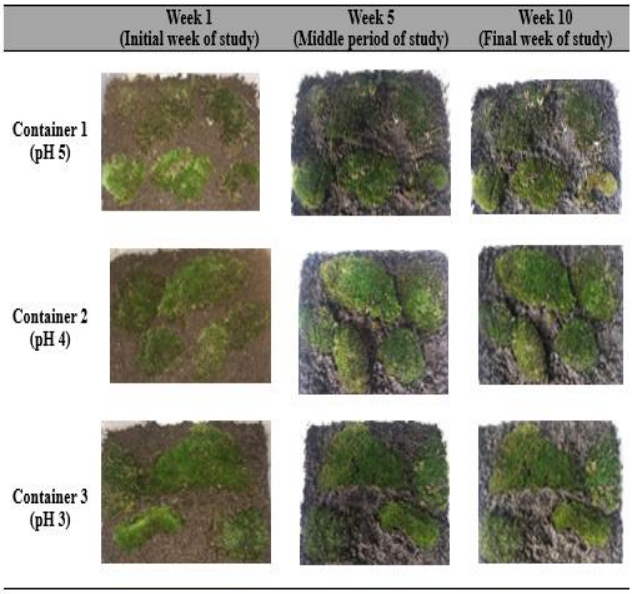
Mean and standard deviation to represent the area covered by moss. One-way analysis of variance (ANOVA) by Statistical Package of Social Science (SPSS) to determine which pH of artificial acid rain that affect the most on moss growth between pH 3, 4 and 5.

III. RESULT

A. Physical observation of treated moss with artificial acid rain

Physical observation of the moss in each container for Week 1, 5 and 10 are presented in Figure I. In week 1, the moss was in a healthy form, in greenish color as can be seen. In week 5 (the middle period of study), as the artificial acid rain exposure increasing, the color of moss in each container at some area has changed from greenish into light pale yellowish. The color of some moss in container 1 (pH 5) and container 2 (pH 4) continuously changed from greenish into pale yellowish as observed in Week 10. However, some moss in container 3 (pH 3) has changed from greenish to pale yellowish, to brownish in color in Week 10.

Figure I: Moss physical observation in each container



B. Moss survivability towards different pH value of artificial acid rain exposure

As the period of artificial acid rain exposure towards moss increased, moss has actively responded to the environment condition. Therefore, some physical changes of the moss such as change of physical appearance color and moss growth disruption were observed. The observation was performed through moss affected area that was represented by grid area in each container. Fig. II shows the grid moss area that are affected by the treatment of artificial acid rain exposure in respective container. The grid area of moss that are affected by the treatment of artificial acid rain exposure in all containers are increased from week to week during the study period. In week 1, there was no grid area of moss affected in all containers as there was no treatment of artificial acid rain was introduced. The grid moss area that are affected was started in Week 2 in container 2 and 3, with one grid area. There were no changes in container 1 in the same week. In week 3, the grid moss area was affected in all containers with one, three and five grid areas for each container. The grid area of moss that were mostly affected were in Week 10, with six grids for container 1, 10 grids for container 2 and 16 grids for container 3.

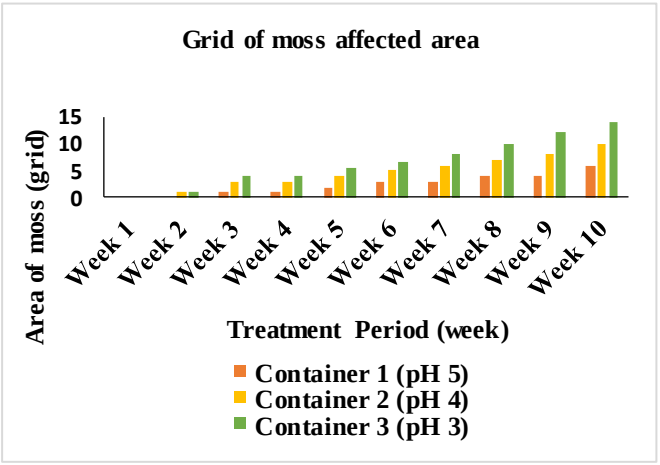


Figure II: Grid of moss affected area at different pH of artificial rain treatment.

C. pH value of artificial acid rain towards moss survivability

The three pH values (pH 3, 4 and 5) were analyzed to determine the most significant contributor towards moss survivability. Table I shows the result of one-way ANOVA. Mean (±SD) of grid moss area affected for pH 5 is 2.33 (±1.85), for pH 4 is 4.70 (±3.11), while for pH 3 is 6.43 (±4.25) with $p < 0.01$. The higher acidity of artificial acid rain, the higher the number of moss grid area that were affected. Indirectly, the survivability of moss was decreased significantly. From the result shown, pH 3 was the most acidic condition that affected the most on moss survivability.

Table I: Most acidic pH value of artificial acid rain affecting moss survivability[a]

pH value	Mean (±SD)	F	*p*-value
5	2.33 (1.85)	12.25	0.000
4	4.70 (3.11)		
3	6.43 (4.25)		

a: Analysis performed: One-way ANOVA
SD: standard deviation; F: ratio of variance

IV. DISCUSSION

A. Moss responses towards artificial acid rain exposure

Moss physical appearance changed after few weeks of acid rain exposure. The difference pH value of artificial acid rain treatment caused the moss to react differently in each container according to different pH value. During week 1, the physical color of moss showed greenish and were in healthier condition as the nearby environment was not exposed with acidic condition. After a few weeks of exposure, and increase frequency of artificial acid rain treatment, the color of moss changed from greenish into pale yellowish, that were observed in pH 4 and pH 5 container.

Some part of moss in pH 3 container turned into pale yellowish, and some chnaged into brownish in color.

The treatment of artificial acid rain has changed moss environmental condition into acidic. This statement can be supported with a study conducted by Patten [17], summarised that an environmental condition can be changed into more acidic condition due to lack of sufficient bases on exchange site with H^+ ions, and acid particles generated from acid rain precipitation. According to McCauley et al., [18], plants may change it physical appearance as to indicate their health. The main cause of growing plant health declining due to the nutrient deficiency or a toxicity condition. The toxicity condition resulting from nutrient for the plant was in excessive amount that will disrupt plant quality and its growth. A plant can be decided as nutrient deficiency based on several symptoms such as growth retardation, chlorosis, interveinal chlorosis, purplish-red colouring and necrosis [18].

From the observation and physical assessment performed towards moss, several parts of moss have been identified in changing colour from greenish into yellowish (pH 4 & pH 5) and to brownish (pH 3). Therefore, moss has endured chlorosis and necrosis. Plant chlorosis is a condition where parts of plants tissue changing into yellowish colour, that indicates chlorophyll reduction. Meanwhile, necrosis can be defined as plant tissues death; turning brown colour from greenish. From the findings of Evans and Lewin [19], plants have been proven to change physical appearance through the production of visible foliar injury of angiosperm and gymnosperm. This condition happened normally in pH condition that is below 3.4. In addition, this study also stated that different plants will react in their own different ways to acid rain or acidic environment [19]. According to study that conducted by Rochefort and Vitt. [20], a hummock species of moss that isolated from water availability, *Tomenthypnum nitens*, are able to grow more efficiently in acidic condition. Their experiment provided nitrate and sulphate as extra nutrients through simulated acid rain exposure. Meanwhile, in the same study, another moss species that live in wetter condition, *Scorpidium scorpioides* showed that the moss was unaffected through the treated simulated acid rain exposure [20]. Thus, a local type of moss should also be tested with the same methodology as to observe their responses towards artificial acid rain.

B. Moss survivability towards different pH of artificial acid rain

Moss survivability are depending on the nutrient that is supplied to itself. The condition of moss that are unable to grow normally is known as nutrient deficiency, where the surrounding condition has become more acidic. This condition can be due to increase in acid precipitation exposure that come from the acid rain exposure. The exposure of moss towards acidic condition has caused increase nutrients source such as sulphur and nitric while reducing other vital nutrients for moss to grow normally. According to Nash III and Nash [21] study, the excessive amount of sulphur dioxide can block plant sexual reproduction activity, hence causing plant unable to reproduce itself [21]. The nutrients available needs to be balanced as to support plant growth and developments, but the nutrient cannot be excessive nor restrained. If the nutrient is excessive, it can cause toxicity or nutrient deficiency respectively [18,22].

The lower the pH value more acidic the rain is. The concentration of air pollutants that made up acid rain which are H_2SO_4 and HNO_3, are also increasing. Some of identified effect of these pollutants towards plant are, the photosynthesis and transpiration rate are altered, promoting abnormalities in plant metabolism, decreasing chlorophyll content and reducing plant yield [23]. Therefore, the statement supports that moss survivability rate will decrease when moss is exposed with acid rain in excessive amount, and the pH of acid rain is lower.

C. pH value of acid rain that affect moss survivability

In a study conducted by Hutchinson et al. [24], they found that moss is unable to survive when the surrounding environment are in acidic condition specifically in pH 3. The pH 3 condition may stimulate deleterious effect on moss growth that cause necrosis in moss [24]. In another study conducted by Smaw and Petersen [25], the most optimum pH value of condition surrounding the moss for their growth and development is in range of pH 6 until 8. However, they also found that moss *B. capillare* species, was hardly to survive in the mid-Atlantic States, U.S.A; a place that have average acid rain of pH 4.2 that also caused the change of soil pH to pH 6 due to acid rain precipitation [25].

V. CONCLUSION

From the findings, this study concluded that moss can be used as bio-indicator for air quality monitoring. As a bio-indicator moss could be used to determine the acidic condition in specific region, that cause by acid precipitation through acid rain. Moss capable of changing its physical appearance that are influenced by the environmental factors such as acidic environmental condition. The data provided from this study showed that, different pH value of artificial acid rain affected the physical changes of moss, that also showed the growth stimulation of the moss. The overall findings of this experimental study support the research hypothesis which is moss survivability is shorten when the surrounding environment is in high acidic condition. pH 3 value is also proven to be the most acidic artificial acid rain that affect the larger area of moss.

As a summary, moss is recommended to be used as bio-indicator; as the moss can be used in passive monitoring. 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 [8].

A. Limitation of study

Despite the positive result of this experimental observation, there are some limitation encountered throughout the study. Holland moss, an imported species was used as a bio-indicator towards the exposure of artificial acid rain which was adjusted to suit our environmental condition. This can influence the survivability of the moss towards exposure of artificial acid rain. Besides, the equipment for air quality monitoring was poorly managed thus making it impossible to assess the moss surrounding environment during the study period.

B. Recommendation for future work

It is recommended that different types of moss specifically, a local type of moss are used as a bio-indicator towards air quality monitoring as it may produce results that suits with our local environmental condition. The equipment for air quality monitoring should be properly managed through calibration for more precise result. The time allocation for this type of study should also be extended to support enough data on the survivability of the moss. To support the finding, chlorophyll extraction of the moss before and after the treatment of artificial acid rain also should be done to measure the chlorophyll content. Other than that, metal analysis on the moss extract could also be measured.

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Huzaifah Masruhan, a student that currently on completing his studies in Bachelor of Environmental Health (Hons.) at Institute of Medical Science Technology (MESTECH), Universiti Kuala Lumpur. He is also a Diploma holder in major of Environmental Health Science graduated in 2016. His research during Diploma is about Swimming Pool Water Quality and the Relationship between Disinfectant Chemical Used. Recently, he led a team of UniKL MESTECH Environmental sections on a trip of Global Students Success Program 2019 to Pattani Province, Thailand for students volunteering and University collaboration. Also, he involved in several international student volunteering programs such as Thailand, Turkey and Indonesia.

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