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Monitoring Heavy Metal Concentrations Using Transplanted Lichen in a Tourism City of Malaysia

Sharifah Nur Amalina Syed Salleh [1] and Azlan Abas [2,*]

[1] School of Environmental Studies, Faculty of Forestry and Environment, Universiti Putra Malaysia, Serdang 43400, Malaysia
[2] Centre for Research in Development, Social and Environment, Faculty of Social Science and Humanities, Universiti Kebangsaan Malaysia, Bangi 43600, Malaysia
* Correspondence: azlanabas@ukm.edu.my

Abstract: Heavy metals are major pollutants in tourist cities due to transportation and urbanization. This study aimed to assess heavy metal concentrations using transplanted lichen in tourist cities. The project was conducted in Malacca, Malaysia, using transplanted *Usnea misaminensis* lichen at ten sampling stations. After one month, these lichen samples were collected and heavy metal analysis was carried out in a lab using ICP-MS. Other factors, such as the number of vehicles, temperature, relative humidity, and wind speed, were also recorded. The results indicated that the heavy metal concentrations in Malacca were higher than at the control station. The ranking of heavy metal concentrations in the study areas was Fe > Zn > Mn > Pb > Cr > Cu. Furthermore, a positive correlation was also found between the number of vehicles and temperature with the heavy metal concentrations determined within the study areas, while relative humidity and wind speed showed a negative correlation with the heavy metal concentrations detected. The usage of lichens to observe and monitor the chemical compositions in the atmosphere is considered to be relevant these days because they allow for long-term data from the ecosystem to be obtained due to their long life span. This research also emphasizes the need for a better plan for Malacca. Local authorities need to re-plan and redesign Malacca to ensure that pollutants can be flushed out, the city looks greener and cooler, and more non-motor vehicles are used as public transport.

Keywords: applied lichen; ecological indicator; environmental management; urban ecology; *Usnea misaminensis*

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1. Introduction

Heavy metals have become one of the main contributors to severe pollution of the environment, compromising our ecosystem's ability to foster life [1,2]. The increase in heavy metals in the environment has a detrimental effect on the ecosystem's health, which may strongly influence the tourism demand, as well as degrade the attractiveness of local tourism destinations [3]. Numerous tourist sites, such as Cairo, Beijing, Naples, and Mexico City, are plagued by increasing air pollution issues that impact the income of their tourism sectors, where it was estimated that they lost 20% of their tourists in 2018 compared with the previous year [4]. According to the WHO (2018), health risks and loss of attractiveness and interest are the main reasons why tourists neglect to visit these polluted cities. Air pollution is the main culprit of health problems, such as stroke, lung cancer, and ischemic heart disease. Studies showed that exposure to even small amounts of particulate matter can lead to high mortality in the Medicare population [5]. Due to this problem, tourists may avoid visiting a less healthy city and might change their destination to another tourist place with better environmental conditions [6].

One of the major factors for increasing air pollution nowadays is the rapid urbanization of an area. The urbanization process creates opportunities for industry and commercial sectors to grow, which leads to exaggerated city expansion. City expansion causes rapid environmental degradation and introduces traffic problems, decreases green space, and increases urban imperviousness. All of these contribute to hazardous pollutants being accumulated and trapped in the atmosphere [7]. Increasing traffic was deemed to be one of the significant contributors of common heavy metals, such as Pb, Zn, and Cu. These heavy metals constitute about 90% of the total particles of heavy metals released into the environment [8]. It was also stated that in urbanized and developing areas where traffic is usually congested, statistics were more significant since there was a relatively high number of vehicles and transportation recorded in such places. The authors of [9] stated that since heavy metals can have detrimental effects on human and ecosystem health and well-being, research on heavy metal air pollution is increasing and becoming more crucial nowadays. Vehicular and transportation-based pollution is becoming worrying, as this is a major source of worsening air pollution in urban areas. Therefore, more investigations need to be made regarding this matter to control the excessive amount of heavy metals being released into the air to limit causing devastating health and environmental-related effects in the future.

The utility of biological components, such as trees, mammals, birds, fishes, and even microbes, to indicate current environmental conditions was widely discovered and implemented into the national policy for some developed countries (the UK, Japan, Germany, etc.). However, for a country like Malaysia, the utility and research about the effectiveness of biological indicators to determine environmental conditions, especially for air pollution, is still lacking. Lichen is one of the most famous and widely used biological indicators to determine air quality. It is a product of the symbiotic relationship between a fungus (mycobiont) and an alga or cyanobacteria (photobiont) [10–12]. They were noted to be sensitive to changes in their surrounding environment, especially air pollution, since they are capable of trapping airborne particles passively. The authors of [13–15] stated that lichen is a very reliable biological indicator because of its sensitivity and the fact that the effects are measurable. Lichens also have the ability to absorb and retain heavy metals from the air due to the lack of cuticles on their leaf surfaces [4,12,16]. Moreover, they are also able to take in water from the surroundings via their thallus surface. In short, the level of pollution in the country can be determined using bio-indicators, such as lichens, as a viable alternative method [17].

Urban tourism is a type of tourism that sells the product of the urban city itself, such as commercial centers, historical buildings, and recreational parks. According to the World Tourism Organization (WTO) [18]), urban tourism was defined as "a type of tourism activity which takes place in an urban space with its inherent attributes characterized by non-agricultural based economy such as administration, manufacturing, trade, and services and by being nodal points of transport. Urban/city destinations offer a broad and heterogeneous range of cultural, architectural, technological, social, and natural experiences and products for leisure and business". As urban areas, tourist cities are not detached from environmental problems, such as air pollution. This situation needs to be settled effectively; otherwise, it could have a negative impact on tourist cities and the tourism sector in general. Malacca is well-known as a common tourist destination, especially during the holidays in Malaysia. There is constant traffic congestion leading up to the city center through the state's entrances, such as through the Ayer Keroh toll gate. This gate saw an increase of about 7.6% in traffic since vehicles pass through the area to get to Malacca [19]. During the 15th International Convention on Malacca Twin Cities (2015), the Chief Minister of Malacca at the time, Datuk Seri Idris bin Haron, stated that Malacca had recorded an astounding 15.03 million tourist arrivals in 2014 alone. He also claimed that ever since Malacca was recognized as a UNESCO heritage site in July 2008, traffic seemed to be worsening, mainly in places such as Banda Hilir. This statement was also corroborated by [20], who reported congestion in popular heritage areas within Macao.

The urbanization process in tourist cities is a major concern in Malaysia nowadays. Due to these problems, this study aimed to assess the heavy metal concentrations using transplanted lichen in Malacca, Malaysia. Furthermore, this study also measured other data in Malacca, such as the number of vehicle motors, temperature, relative humidity, and wind speed. This could provide information on how tourist cities have been degraded by urbanization or tourism activities, which will hopefully alert the authorities and society that tourist cities are fragile and that special treatment and planning are needed.

2. Materials and Methods

2.1. Study Area

Malacca was chosen as the study area for this project for several reasons. According to [21], the air pollution in the state is worsening due to urbanization and a high number of motor vehicles and transportation that emit pollutants and heavy metals into the air. They also reported that the carbon dioxide level found within the study areas was quite high at 934 ppm. Thus, it is very suitable and practical to use Malacca as the study area for this research project since the amount of air pollution can be evaluated by measuring the concentration of heavy metals in lichens transplanted around the city. The heavy metals assessed were iron (Fe), zinc (Zn), manganese (Mn), lead (Pb), chromium (Cr), and copper (Cu) since they were documented to be the primary pollutants emitted by vehicles [22]. Due to the high number of vehicles and continuous development being done, which contribute to air pollution within the state, 10 sampling stations were chosen (Table 1 sampling stations GPS coordinate and Figure 1 sampling locations map). All these sampling stations were located close to tourist sites in Malacca, with six located near the city center, three located at Ayer Keroh (2nd most famous tourism site in Malacca, Malaysia), and one sampling station located near A Famosa Resort (renowned holiday place).

Table 1. Coordinates for transplanted *Usnea misaminensis* lichen at study sites.

Site	GPS Coordinates
1	N 2°38′19.348″, E 101°54′12.776″
2	N 2°27′13.932″, E 101°51′18.576″
3	N 2°29′46.224″, E 101°50′48.658″
4	N 2°30′4.052″, E 101°50′14.102″
5	N 2°31′44.768″, E 101°49′17.876″
6	N 2°31′26.497″, E 101°47′47.605″
7	N 2°31′14.833″, E 101°48′0.194″
8	N 2°33′37.631″, E 101°49′2.308″
9	N 2°35′39.379″, E 101°51′32.42″
10	N 2°40′29.681″, E 101°55′26.794″

2.2. Sampling Procedures

The *Usnea misaminensis* lichen samples were collected at the control site, which was Bukit Larut in Perak (N 4°51′43.6″ E 100°47′39.5″), using a clean ceramic knife and a pair of gloves. The samples were then placed in labeled, sealed paper bags to prevent them from absorbing pollutants elsewhere. Data such as the GPS coordinates, relative temperature, humidity, and wind speed were also taken at the control area. Temperature and humidity were measured using a thermo-hydrometer (E-Sun ETP101), while data on the wind speed were taken using a thermo-anemometer (Extech 451112). Figure 2 shows the *Usnea misaminensis* lichen found at the control site.

The lichen samples (Figure 3) were then taken to the study area and transplanted onto trees at 10 stations around the city. A total of 50 g of lichen were put in punctured paper bags and placed on three different trees 1.5 m above the ground facing air pollution sources, which were the roads, for a month. Data such as GPS coordinates, relative temperature, and humidity were noted and recorded in each station of the study area. The number of vehicles was recorded once every week on three different occasions, in the morning, afternoon, and evening, for each station. The vehicles were counted for an hour each time, and the total number of vehicles was obtained. These were then done consecutively for four weeks, and the average number of vehicles per week was calculated. Meteorological data, such as the temperature, relative humidity, and wind speed, were taken at the control and study areas. The meteorological data at the study sites were taken once a week in the morning, afternoon, and evening three times each time for a month and the average data recorded for each time were tabulated.

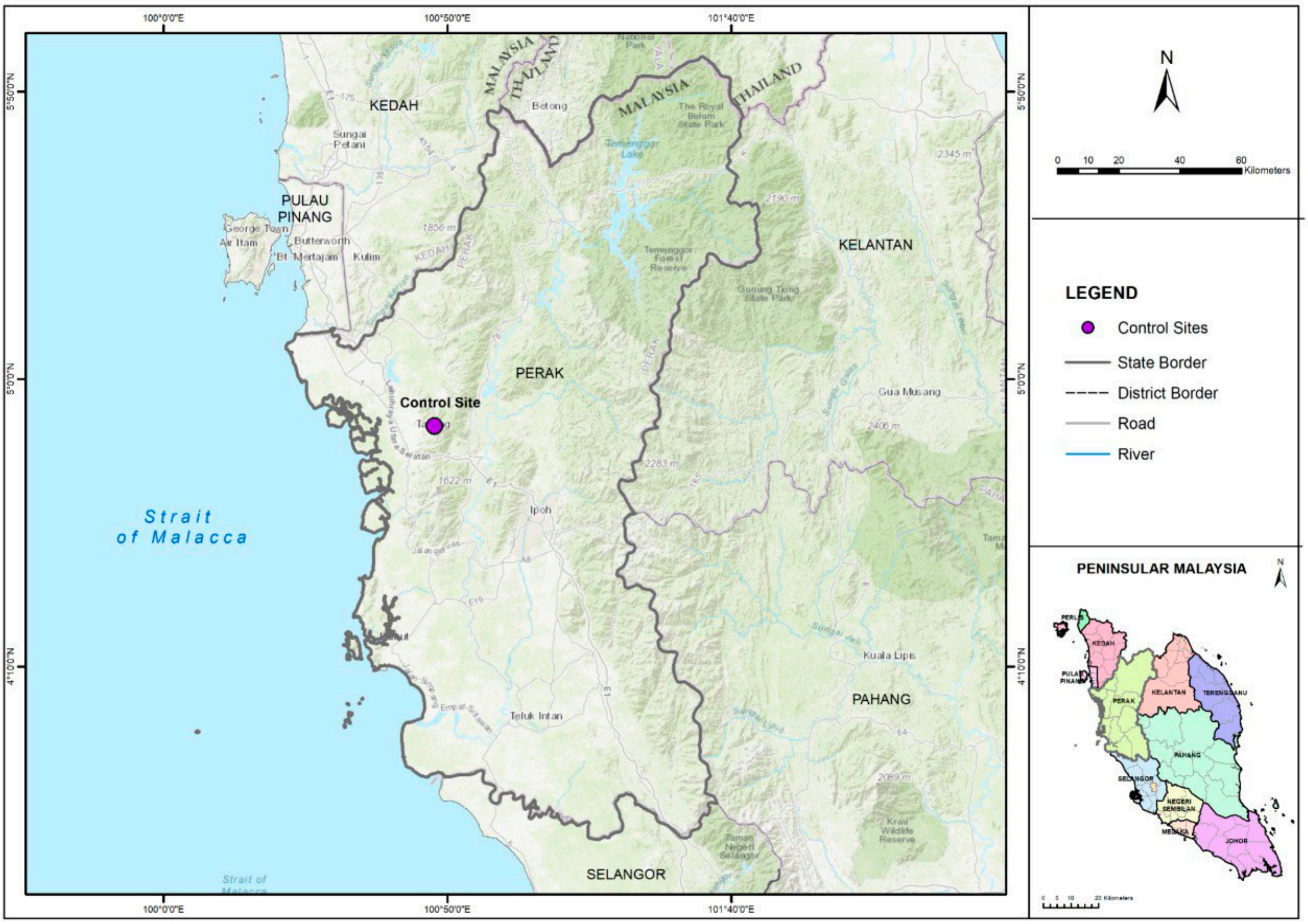

Figure 1. Map of control area (Bukit Larut).

2.3. Laboratory Analysis

After about a month, the lichen samples were collected, placed in sealed containers, and taken to the laboratory for analysis. In the laboratory, the lichen samples were first air dried for about two days in the open air at the laboratory. Then, the samples were heated in the oven for another two days at about 50 °C in order to remove any excess moisture from the samples.

Any debris or dust in the samples was then picked out carefully using clean tweezers, and the *Usnea misaminensis* samples were later crushed into a powder form. Then, 1.0 g of each lichen sample from the control area and each station in the study areas were weighed for digestion. All of the glassware instruments used, such as the beakers and conical flasks, were soaked with nitric acid overnight to prevent any technical error from occurring when analyzing the data [23].

After this, the digestion process was carried out by mixing 5 mL of concentrated nitric acid and 15 mL of perchloric acid into one conical flask. The samples were then heated on a hot plate until the initial volume of the samples was reduced by half. The samples were then left to cool and rinsed using 5 mL concentrated nitric acid before filtering them into a 150 mL conical flask using Whatman No. 42 filter paper [23].

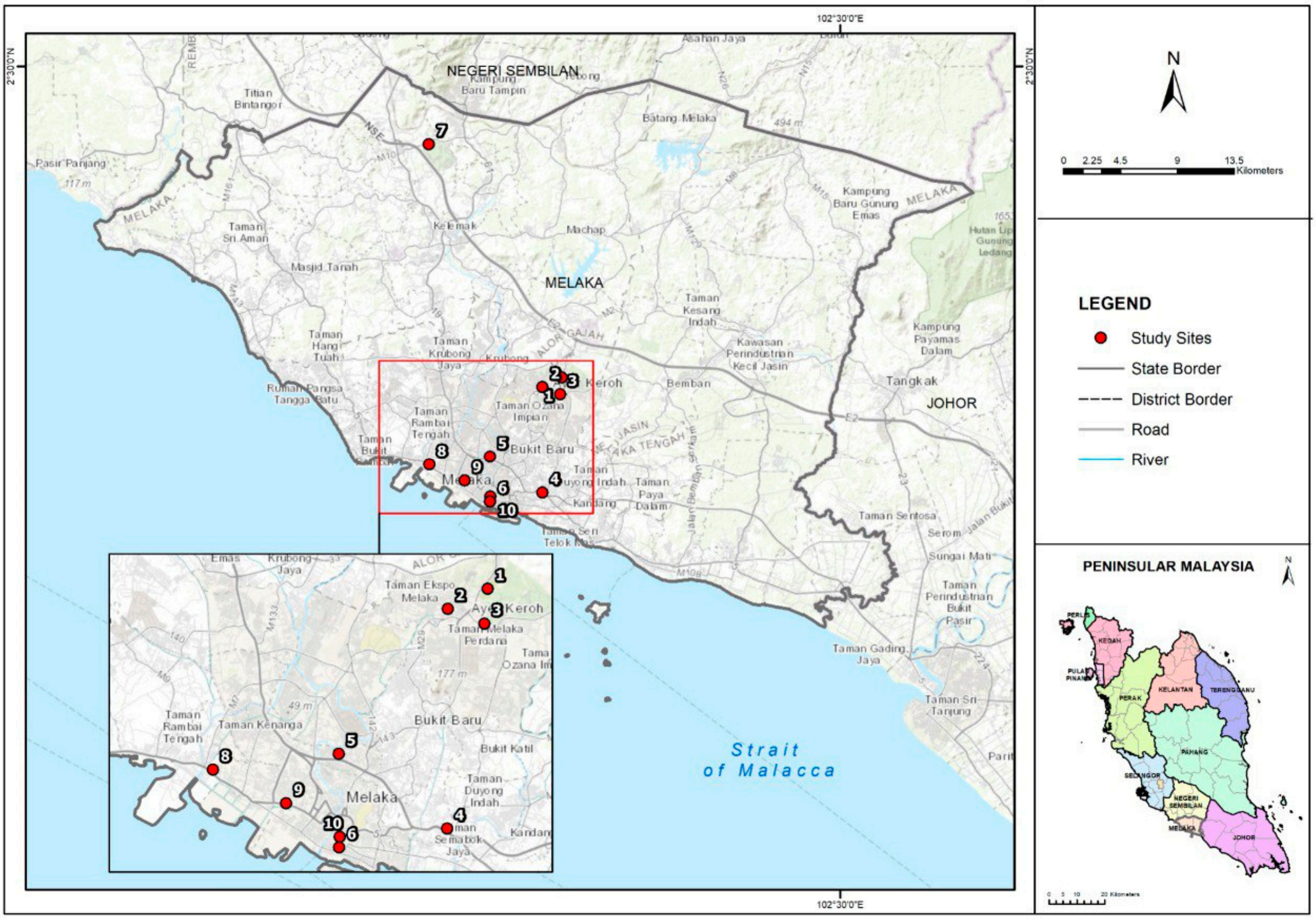

Figure 2. Map of transplanted Usnea misaminensis lichen at study sites in Malacca.

During the filtration process, the samples were rinsed with 5% nitric acid and the filtrates were diluted to 50 mL using 5% nitric acid. The diluted samples were then placed in cartels to detect heavy metals, namely, Cu, Mn, Pb, Zn, Fe, and Cr, using inductively coupled plasma mass spectrometry (ICP-MS). The experiment was then repeated three times [4].

2.4. Statistical Analysis

Statistical analyses used in this study included the Anderson–Darling normality test, one-way ANOVA, and Pearson's coefficient correlation. The Anderson–Darling normality test was done to determine whether the results followed a normal distribution for parametric tests, such as one-way ANOVA, to be carried out. One-way ANOVA using Statistical Package for Social Sciences (IBM SPSS Statistics Software, 22.0 version) was then done to determine the significant differences in concentration of heavy metals found in lichens between the control and study area and between the stations involved in the study area. In addition, Pearson's coefficient correlation was also used to evaluate the relationship between the number of vehicles recorded in each station of the study area with the concentration of heavy metals found in lichens transplanted in the station.

Figure 3. Usnea misaminensis lichen found in Bukit Larut (control area).

3. Results

3.1. Concentration of Heavy Metals Accumulated in Transplanted Lichen

Table 2 shows the concentration of heavy metals determined in the transplanted lichen samples collected from the control station in Bukit Larut, Perak, and 10 study sites within Malacca after being analyzed using ICP-MS. The table shows that Fe had the highest concentration level of heavy metals measured compared with the other heavy metals, ranging between 32.075 to 71.545 µg/g and with an average of 49.61 µg/g. This was followed by Zn, Mn, Pb, Cr, and finally Cu, with the lowest average concentration level detected in the lichen samples at 1.266 µg/g.

The Anderson–Darling normality test (Table 3) showed a *p*-value greater than 0.05, indicating that the results followed a normal distribution. The significant difference between the concentrations of heavy metals accumulated in the *Usnea misaminensis* lichen samples collected at the control site, Bukit Larut, and those transplanted within the study sites in Malacca was obtained using one-way ANOVA (Table 4). Based on the table shown above, it can be seen that all of the heavy metals, except Cu, showed significant differences, as the *p*-values were lower than the significance level ($p < 0.05$). Thus, it can be said that the study areas were significantly polluted with the heavy metals studied compared with the control site when tested using the lichens transplanted.

Table 2. Average concentrations of heavy metals found in transplanted lichen samples.

Site	Concentration of Heavy Metals in the *Usnea misaminensis* Lichen (µg/g)					
	Fe	Zn	Mn	Pb	Cr	Cu
Control	15.87 ± 0.18 *	2.11 ± 0.25 *	0.84 ± 0.04 *	0.52 ± 0.09 *	0.24 ± 0.02 *	0.54 ± 0.11
1	29.35 ± 7.3	13.18 ± 9.4	13.57 ± 7.4	1.31 ± 3.2	1.06 ± 4.5	0.82 ± 0.3
2	52.77 ± 17.0	19.96 ± 19.7	11.43 ± 3.2	2.08 ± 13.0	1.29 ± 2.9	1.29 ± 0.8
3	57.99 ± 15.6	15.36 ± 12.2	11.60 ± 3.7	1.44 ± 4.3	1.03 ± 1.5	0.98 ± 0.7
4	37.94 ± 13.0	16.79 ± 14.3	13.22 ± 7.8	1.79 ± 5.2	1.23 ± 2.3	1.02 ± 0.8
5	45.02 ± 6.8	16.41 ± 13.6	12.21 ± 7.5	3.55 ± 13.7	1.54 ± 2.7	2.24 ± 1.2
6	40.68 ± 8.0	19.25 ± 19.2	21.90 ± 11.5	1.39 ± 3.4	1.88 ± 2.8	0.99 ± 0.7
7	35.93 ± 9.1	14.92 ± 12.0	14.05 ± 8.5	1.39 ± 3.7	1.19 ± 1.0	0.83 ± 0.4
8	24.71 ± 7.3	11.15 ± 7.9	6.95 ± 1.5	1.27 ± 1.3	0.91 ± 0.8	0.68 ± 0.6
9	29.46 ± 7.6	13.49 ± 11.5	11.15 ± 4.7	1.36 ± 1.6	1.37 ± 1.2	0.93 ± 0.3
10	38.84 ± 12.5	16.88 ± 15.7	12.63 ± 5.6	1.72 ± 2.1	1.15 ± 1.2	0.99 ± 0.6
Average	39.27 ± 10.5 *	15.74 ± 7.7 *	12.87 ± 3.7 *	1.73 ± 0.7 *	1.27 ± 0.3 *	1.08 ± 0.4

* Significant differences were detected in all groups since $p < 0.05$ using ANOVA.

Table 3. Anderson–Darling normality test.

Heavy Metal	N	Mean	A-D Value	*p*-Value
Fe	10	39.27	0.25	0.74
Zn	10	15.74	0.19	0.90
Mn	10	12.87	0.93	0.02
Pb	10	1.73	1.46	0.00
Cr	10	1.27	0.38	0.41
Cu	10	1.08	1.43	0.00

Significance level: $p > 0.05$.

Table 4. Result of the one-way ANOVA carried out for each heavy metal in the control and study areas.

Heavy Metal	*p*-Value	Significance
Fe	0.00	Significant
Zn	0.00	Significant
Mn	0.00	Significant
Pb	0.01	Significant
Cr	0.00	Significant
Cu	0.08	Not Significant

Significance level: $p < 0.05$.

3.2. Analysis of Heavy Metals Concentrations with External Factors

External factors, such as the number of vehicles and meteorological data, are shown in Tables 5 and 6. Pearson's correlation coefficient test was done to determine the correlation or relationship between the number of vehicles and meteorological data in the study sites with the concentration of heavy metals accumulated by the lichen samples. All the data are shown in Table 7. All external factors had strong and significant relationships with the heavy metals concentrations from transplanted lichen with $p < 0.01$. For the number of vehicles, the analysis showed that a higher number of vehicles increased the concentrations of heavy metals. This was the same for temperature, as an increase in temperature also increased the heavy metals concentrations. Meanwhile, relative humidity and wind speed showed a negative relationship with the heavy metals concentrations.

Table 5. Average number of vehicles recorded per hour at each study site.

Site	Types of Vehicle			
	Motorcycle	Car	HGV/Bus	Total
1	1740	2580	120	4440
2	1680	2580	120	4380
3	720	1260	120	2100
4	2400	4800	660	7860
5	1380	6120	660	8160
6	3720	7500	780	12000
7	2460	3360	300	6120
8	480	3720	1320	5520
9	1620	3660	180	5460
10	1320	3600	120	5040

Table 6. Average temperature, relative humidity, and wind speed measured at each study site.

Site	Time	Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)
1	08:00	32.4	73.7	2.20
	13:00	34.0	67.0	2.09
	17:00	32.6	60.1	2.16
2	08:00	32.0	72.3	3.82
	13:00	33.5	67.0	3.02
	17:00	32.2	60.1	2.81
3	08:00	32.2	65.3	5.90
	13:00	33.5	55.0	6.30
	17:00	32.2	53.0	5.51
4	08:00	31.4	65.0	5.62
	13:00	32.9	56.3	6.55
	17:00	31.9	59.7	6.16
5	08:00	31.5	60.0	3.02
	13:00	32.1	55.7	3.53
	17:00	32.8	56.7	3.60
6	08:00	31.1	62.0	1.51
	13:00	31.3	54.7	0.98
	17:00	32.1	53.7	0.98
7	08:00	33.0	58.0	4.10
	13:00	32.0	54.7	3.56
	17:00	31.1	53.7	3.92
8	08:00	32.1	76.3	6.37
	13:00	32.4	64.7	6.01
	17:00	31.1	71.0	6.55
9	08:00	30.5	67.3	4.82
	13:00	31.2	65.3	4.68
	17:00	30.5	70.0	4.39
10	08:00	31.9	70.3	4.32
	13:00	31.7	69.7	4.50
	17:00	31.1	65.7	4.14

Table 7. Results for Pearson's correlation coefficient test between the external factors recorded and concentrations of heavy metals in lichen samples at the study sites.

		Concentrations of Heavy Metals
Number of vehicles	r	0.965
	p	0
Temperature	r	0.694
	p	0.026
Relative humidity	r	−0.861
	p	0.001
Wind speed	r	−0.858
	p	0.001

Correlation was significant at $p < 0.01$.

4. Discussion

Overall, all heavy metals recorded at the study sites showed higher concentrations compared with the control site. This was unsurprising, as the control site (Bukit Larut) is known as the wettest area in Malaysia, with an average rainfall of 4000 mm [24]. Furthermore, Bukit Larut's accessibility is strictly limited, as visitors can only reach it using jeeps provided by the State Park. This means that only a small amount of heavy metals from motor vehicles is emitted in its vicinity. However, in Malacca, which is one of the most famous tourist cities in the world and home to a world heritage site that welcomes millions of tourists from all over the world every year, heavy metal concentrations were considerably higher and at a hazardous level.

Analysis of the concentration of heavy metals in the *Usnea misaminensis* lichen samples showed that the lichen samples were able to detect and absorb six main heavy metal elements, namely, Fe, Zn, Mn, Cu, Pb, and Cr, in both the control and study areas. According to [25,26], Pb, Cr, Cu, and Zn are the heavy metals most commonly used as indicators for heavy metal pollution in the environment, with Pb being one of the metals with the greatest concern due to the danger it poses when it is over the safe limit. Most of the heavy metals were emitted from motor vehicles. According to [27,28], Fe is usually sourced from fuel combustion in vehicle motors, while Zn and Mn are well-known components of automobile tires and brake pads and Zn can be found in lubricating oils. Other than that, Cu is known to mainly be emitted or released by copper-related activities, such as metal-producing industries. Hence, it can be said that samples from both areas contained a low concentration of Cu because of the fact that there were no copper mining processes or industries nearby the control areas or study areas where the samples were transplanted. Pb may be released into the air or the atmosphere from heavy traffic due to the consumption or utilization of leaded petrol and gasoline as automobile fuels. This was because the Pb particles emitted through the exhaust of vehicles were released as an aerosol into the environment. Other documented sources of Pb pollution are industries that use Pb as part of their components, such as when manufacturing batteries [29,30]. According to [31], Malaysia no longer authorizes or permits leaded fuel or petrol to be sold at pumps in stations nationwide. Thus, this explains why there was a very low concentration of Pb that the lichen samples detected in both areas. Lastly, Cr was one of the most common additives used in unleaded gasoline or fuel for vehicles. Therefore, this explains why it could be traced in the lichen samples. Since the study areas recorded higher vehicular activities, they had a slightly higher concentration reading compared with the control samples. However, [30] also noted that Cr can mostly be found close to textile and metal industries, which is why there was only a little Cr that was absorbed by the samples from both areas. Neither site was nearby chromium-related industries or factories.

Furthermore, the results also showed a very strong correlation between vehicle number and heavy metal concentration with r = 0.965. The number of vehicles in Malacca was the main factor for its high concentration of heavy metals. This statement is supported by [32], who concluded that the areas or roads with the highest traffic density have the highest concentration of heavy metals. The type of vehicle also influences heavy metal concentrations. Motor vehicles, such as trucks and buses, usually use diesel as their source of fuel. This kind of fuel emits higher heavy metal concentrations compared with unleaded petrol. As a tourist city, buses are the main transportation in Malacca, as they are more accessible and cheaper for tourists. Because of this, heavy metal concentrations in Malacca are higher compared with non-tourist cities.

The temperature in Malacca also showed a positive relationship with the heavy metal concentration since r = 0.694. According to [33], concentrations of heavy metals in the air are higher when the temperature is high due to the low level of precipitation occurring in the atmosphere. This prevents contaminants in the air from being cleansed and thus produces higher pollutant concentrations in the environment. Furthermore, precipitation is also lacking in Malacca due to the decreasing number of green and water body areas. Green areas are vegetated areas including trees, ornamental plants, shrubs, and grassland. A decrease in green areas also decreases air humidity, as provided through photosynthesis. Waterbody areas can help with decreasing the temperature by providing vaporized water to the atmosphere through evaporation. Humidity and temperature are usually related. Temperatures will decrease when relative humidity increases. In the case of Malacca, relative humidity has a strong negative relationship with the heavy metal concentrations (r = −0.861). Studies by [34,35] showed that high relative humidity correlates with low levels of heavy metals found in dry air. Like temperature, humidity is closely related to precipitation. Decreasing green and water body areas due to tourism site development have reduced the relative humidity in Malacca.

The wind speed in Malacca showed a strong negative relationship with heavy metal concentration since r = −0.858. This statement is also supported by [36], who reported that low wind speed correlates with a higher concentration of heavy metals in the air because there is less diluting capability. Wind speed is always related to urban imperviousness. Usually, urban areas will have higher imperviousness compared with rural areas. Malacca has high urban imperviousness, which results in low wind speed. Wind speed is important in order to flush out all the pollutants emitted in the urban area to a less populated place, such as a forest. However, with higher density and imperviousness, wind cannot flow through the area and the pollutants will remain in the city, affecting urban residents and tourists.

5. Conclusions

In this study, transplanted *Usnea misaminensis* lichen was used to analyze the heavy metal concentration in Malacca. This study found that the heavy metal concentration in Malacca was higher that at the control station. Most of the heavy metals found in the transplanted lichen were emitted from motor vehicles. The type of motor vehicle plays a major role in the heavy metal concentration in Malacca. Heavy metals from motor vehicles are usually emitted through the process of incomplete fuel combustion and braking (brake pads and tires). Hence, frequent vehicle braking and stopping will increase heavy metal emissions. This often happens during heavy traffic periods and in congested areas. This study also found that the number of vehicles and environmental factors, such as temperature, humidity, and wind speed, had a strong relationship with the concentrations of heavy metals. An increase in the number of vehicles and temperature increased the heavy metal concentrations. In contrast, an increase in the humidity and wind speed reduced the concentrations of heavy metals at the study sites.

This study also emphasizes the need for a better plan for Malacca. As a famous tourist city, Malacca needs an urgent plan to tackle the issue of the increasing number of motor vehicles, lack of green and water body areas, and high urban imperviousness. These issues not only worsen the heavy metal concentration but also cause other urban problems. An increasing number of vehicles in a high imperviousness area will produce constant noise pollution. A lack of green and water body areas will make Malacca consistently dry and less humid. This will make residents, and more importantly, tourists feel very unpleasant in Malacca. All these problems will eventually make Malacca lose its livability and attractiveness as a great tourist city. To avoid these problems, local authorities must re-plan and redesign Malacca to ensure that pollutants can be flushed out, make the city greener and cooler, and promote non-motor-vehicle-based public transport. Lichens should also be fully utilized as biological indicators to determine and assess air quality. Besides being sensitive to changes, they were also able to withstand extreme conditions and pressure, making them highly durable. Therefore, the implementation of biological indicators, such as lichens, should be carried out and further research and studies need to be done in order to unlock the full potential of this organism.

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