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Measuring air quality using lichen mapping at Universiti Kebangsaan Malaysia (UKM) Campus

Mohd Wahid Samsudin*, Laily Din, Zuriati Zakaria, Jalifah Latip, Tukimat Lihan, Abdul Aziz Jemain & Fazri Samsudin

Faculty of Science and Technology, Universiti Kebangsaan Malaysia

Abstract

A study relating air quality with lichens was conducted at Universiti Kebangsaan Bangi campus. The aim is to determine the land of pollution in the area where the lichens are going. The site fulfils many characteristics for a good location such as the age of the campus which is more than 40 years, population density, buildings, traffic in the campus as well as at its periphery, hills surrounding the buildings, forest reserve, recreational gardens as well as daily activities in the campus. The palm trees in UKM comprise of 36 species, among them, *Roystenia oleracea*, *R. regia, Veitchia merillii*, *Cocos nucifera*, *Bentinckia nicobarica*, *Archontophoenix alexandrae*, *Livistona rotundifolia, Areca catechu* and *Chrysalidocarpus lutescens* which are good hosts to lichens. Twenty seven areas around the UKM campus were selected and they consist of 110 palm trees. The nitrogen content and pH values of each host at a height of 1 m and 2 m above the ground were collected. Each palm tree was selected according to the geographical position such as near to a road, hill, forest reserve, river, golf course and students' residences. The locations were recorded using GPS and all data were entered in the GIS. The pH at the height of 1m of the pal host was 4.87±0.48, whilst the pH value at the height of 2 m was 4.88±0.46. The nitrogen content at the height of 1 m was 0.5940±0.4437 % and for the height of 2 m was 0.6586±0.5698 %. The lichens growing on the host are epiphytic lichens from the genus/species *Arthonia, Caloplaca, Chrysothrix, Dirinaria, Hyperphyscia adglutinata, Laurera, Lecanographa, Lecanora, Parmotrema tinctorum, Parmotrema praesorediosum, Physcia, Pyxine cocoes, Rinodina, Trypethelium* and *Graphidaceae*. Quadrant study at each host for epiphytic lichen gave values for air quality at the study site because each lichen will give a specific score according to its tolerance towards air pollution. The determination of air quality can be determined by the total lichen score in each quadrant. The results showed that the air quality can be categorized to 4 levels, that is, a score more than 10 is clean air, 0-10 is moderate, -10 to 0 is slightly polluted and less than -10 is highly polluted. The study showed that the location of the lichen at the palm host at UKM is consistent to the air quality. Overall, the Air Quality Score at UKM is 8.39±4.33 which is in the moderate category.

Keywords : Air Quality; lichens; UKM

1. Introduction

* Corresponding author. Tel.: +6-03- 8921-5449; fax: +6-03-8925-6086
E-mail address: wahid@ukm.my

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Lichens have been used as an indicator for air quality since the year 1866 (Nylander 1866; Kricke & Loppi 2002; Conti & Cecchetti 2001). 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).

As an indicator of air quality, lichens do not have cuticles to control the exchange of water, nutrients, gas and other particles with the external environment. Instead, the absorption of nutrients is from the atmosphere and not from the root system. Lichens have a slow rate of growth and a slow rate of tissue repair (damaged tissue) (Asta et al., 2002). Lichen growth in the forest is influenced by various factors, amongst them are the availability of dead trees, pH of the bark, air quality, relative humidity and exposure to sunlight (Barkman, 1958; Coppins, 1984; Hawksworth & Hill, 1984). Determining the Lichen Diversity Value (LDV) and Index Atmospheric Purity (IAP) are the main methods of monitoring the environmental change especially relating to air pollution in many European countries such as Italy (Gombert et al., 2003), Portugal (Cepogo et al., 2008), France (Gombert et al., 2004), London (Larsen et al., 2007) and Slovenia (Jeran et al., 2002).

The rise in human population resulted in the rise for the demand for energy and resources for industry as well as an increase in agricultural activities to produce more food. In industrial areas, fossil fuels continuously release by products such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) causing air pollution as well as acid rain (Godinho et al., 2008; Arya, 1999). The release of pollutants from motor vehicles also contributes to air pollution in urban areas. Examples of the pollutants are NO, NO_2, CO, CO_2, poly-aromatic hydrocarbons (PAH) and heavy metals such as Pb (Larsen et al., 2007).

From the Chemistry aspect, the main factor influencing the diversity of lichens is the hydrogen ion concentration or pH. This phenomenon is supported by a majority of researchers, among are Carlisle et al. (1967), Brodo (1961), Hale (1955), Culberson (1955b), Barkman (1958), Du Rietz (1945) and Fabiszewski (1968). The acidity and the alkalinity are able to react with the lichen talus in different ways. Most minerals and organic matter exist at different chemical conditions with a different pH values. The rate of distribution of the materials varies according to the pH value, whereby some of the materials become toxic under acidic conditions but are not harmful under neutral conditions.

2. Material and Method

The study area comprises 27 areas consisting of 110 trees which were selected according to some characteristics surrounding the campus of Universiti Kebangsaan Malaysia, Bangi, Selangor. The location of of each tree is recorded using GPS. The method of determination of air quality is to use a counting technique for the frequency of lichen growth in 10 squares of a quadrant where the frequency is the number of squares on the quadrant which contain the lichen. The lichens are categorized into three groups based on the tolerance towards air pollution, i.e. tolerant, moderate and sensitive group. Table 1 shows the division of lichen species according to their tolerance towards air pollution.

Table 1. Lichen species according to their tolerance towards air pollution

Tolerant species	Moderate Species	Sensitive species
Pyxine cocoes	*Dirinaria*	*Parmotrema tinctorum*
Hyperphyscia adglutinata	*Chrysothrix*	*Parmotrema praesorediosum*
	Trypethelium	*Physcia*
	Lecanora	
	Rinodina	
	Lecanographa	
	Laurera	
	Arthonia	
	Caloplaca	

Source: Lichen Investigator. www.trf.or.th & www.britishcouncil.or.th

The frequency counted will be used to calculate the frecuency points and the air quality score of each area. The tolerance group will give a (-1) for each frequency of lichen in the quadrant. If in the investigated square only the tolerance group found, double the minus score if otherwise there is no need to double the score. The moderate lichens will give a score of (+1) for each frequency in one quadrant. For the sensitive lichens, the frequency of the lichen at each quadrant will be multiplied by 2. The air quality score on each tree is equivalent to the average of the total score of the frequency of the selected tree from 4 directions, i.e. north, south, east and west. The air quality score for one area is the average for the total air quality score of all the trees in the specific area. The air quality score of UKM is the average for the total air quality score for all the 27 areas studied.

$$\text{Air Quality Score (One area)} = \frac{\text{Total Air Quality Score for each tree in the study area}}{\text{Number of trees in the study area}} \quad (1)$$

$$\text{Air Quality Score (UKM)} = \frac{\text{Total Air Quality Score for study areas}}{\text{Number of study areas}} \quad (2)$$

The air quality score obtained will be assessed to determine the level of pollution in the areas where the lichens are growing. A score of more than 10 will indicate that the area is clean and free from pollution. If the score is 0-10, the level of pollution is moderately clean. The area is slightly polluted when the score is -10 to 0 whilst the area is heavily polluted if the score is less than -10.

The study area and trees were identified. The circumference of each tree selected was measured and recorded. If the circumference is less than 80 cm, the direction of study is reduced from 4 to 2, either north and south or east and west. For each tree, a quadrant of 20x50 cm^2 is placed vertically on the bark at a height of 1 m from the ground and facing the north direction. The lichens are then identified according to the three groups, i.e. tolerant, moderate and sensitive lichen groups. Magnifying len was used to observe the morphology of the lichens and the lichens were identified with the help of a lichen expert. The number of the lichens were counted and recorded to determine the frequency of the lichens. The frequency score was calculated and recorded. The previous steps were repeated for the same tree facing south, east and west direction. The same method was applied for each palm tree in the study area. The air quality score for each study area was calculated according to equation 1 above. For each quadrant, about 4 g of the bark of the palm tree was scraped and collected.

The sample was air dried and ground using a blender (Super Blender ASPPORO™) until it becomes a powder. The powder was weighed (about 0.5 g) and transferred to a conical flask (100 mL). Distilled water was added until up to 50 mL and mixed with the sample. The conical flask was covered with an aluminum foil and left to stand overnight. The pH of the sample was determined using the pH meter (827 pH Lab Metrohm Swiss Made). The solution was mixed with a glass rod before the pH meter is immersed in the solution. Readings are taken after 30 seconds and entered in a table. The pH meter is rinsed with distilled water and wiped with tissues. The steps are repeated for all samples in the study area.

The nitrogen content is conducted using Thermo-Finnigan Flash EA 1112 Analyzer. The apparatus consist of auto sampler, oxidation and reduction tubes in oven, water trap, CO_2 trap (when Nitrogen is the main component), gas chromatography column, detector and software for thermal (300 Eager) for integrating analytical results. The bark of the palm trees was ground to powder, weighed (2-3 mg) and recorded. The bark samples were inserted into tin capsules and placed in the oven at a temperature 950 ºC (pure oxygen environment). The tin capsule underwent exothermal combustion raising the temperature to about 1800 ºC, causing the sample to oxidize. The combustion products were then passed through an oxidizing catalyst (copper oxide / CuO) at 950 º C using Helium as the carrier gas to ensure complete oxidation. The products were then passed through a second oven containing Copper (Cu) catalyst at 650 ºC where the reduction process takes place. After reduction, the mixtures of gases were separated to the main components by gas chromatography. The component gases were detected using a thermal conductivity detector at 50 ºC. Lastly, the computer software (300 Eager) combined the signals and calculated the amount of N, C, H and S in the samples. The total amount of time for each analysis is 10 minutes.

3. Results and Discussion

Most epiphytic lichen species prefer substrate with specific chemical and physical qualities, therefore, choose to grow on certain tree species. One of the main factors, affecting their occurrence is the acidity of the bark, Table 2.

Table 2. PH values and percentage of nitrogen from barks of trees in the study area

Tree Species	pH value		Nitrogen Values (%)	
	1 m	2m	1m	2m
Roystenia regia	4.70±0.30	4.78±0.27	0.4584±0.4839	0.4507±0.6901
Livistona rotundifolia	4.42±0.12	4.48±0.13	0.2101±0.0055	0.2142±0.0265
Bentinckia nicorbarica	4.63±0.18	4.57±0.17	0.5796±0.6276	0.9219±1.0974
Veitchia merrillii	4.57±0.19	4.55±0.17	0.6742±0.6818	0.6809±0.6668
Roystenia oleracea	4.84±0.27	4.85±0.25	0.4893±0.2664	0.5519±0.2594
Archontophoenix alexandrae	4.84±0.19	4.89±0.25	0.2508±0.1309	0.7116±0.7200
Cocos nucifera	4.50±0.06	4.55±0.13	0.7813±0.1693	0.8249±0.1636

Table 2 shows the pH values and percentage of nitrogen from the bark of trees on the study area. Acidic pollutants reduced bark pH and alkaline pollutants increase it. Beside the indirect influence causing a change in substrate pH, also direct effect on lichens; for example, the toxic nature of SO_2 and NO_2 are probably the primary factor affecting lichen physiology rather than acidity of the bark (Hawksworth & Hill, 1984).The air quality score, pH values and nitrogen content of an average of 3 palm trees in each study area are listed in Table 3.

Table 3. The air quality score, pH values and nitrogen content of an average of 3 palm trees in each study

Area	Air Quality Score (Area)	Pollution Level	pH value (Area)	Nitrogen Content (%)
Green House	32.75±13.67	Clean	4.49±0.03	0.1554±0.0487
Green House (Across Road)	19.5±8.19	Clean	4.65±0.14	0.6699±0.9397
Green House (Terrace E, F, X, P, Pond 7)	17.33±10.98	Clean	4.57±0.22	0.1641±0.0518
Biocompatibility Laboratory	8.00±2.50	Moderately Clean	4.67±0.10	0.6149±0.9144
Chemistry Building FST	8.67±8.10	Moderately Clean	4.41±0.13	0.2448±0.1306
Nuclear Science	10.50±4.77	Clean	4.70±0.07	0.8759±1.0626
Aminuddin Baki College	(-1.33)±13.04	Polluted	4.41±0.16	0.6459±0.7954
Ungku Omar College	(-1.50)±4.87	Polluted	4.89±0.13	0.3373±0.3619
Inner Gate to Outer Circle-2	5.83±9.78	Moderately Clean	4.76±0.02	0.2718±0.1126
Agriculture Unit	26.67±12.58	Clean	4.57±0.09	1.1374±0.9676
Ibrahim Yaakub College	7.08±10.82	Moderately Clean	5.07±0.09	0.1735±0.0839
UKM Mosque (Near Road)	(-6.25)±4.25	Polluted	4.57±0.26	0.3890±0.1413
UKM Mosque (Middle Section)	(-2.58)±1.88	Polluted	4.99±0.07	0.1965±0.0298

UKM Mosque (Front Section)	10.33±1.61	Clean	4.75±0.13	0.3022±0.1763
Aman Building	(-7.83)±5.03	Polluted	4.58±0.17	0.2013±0.0358
DECTAR (Front Section)	2.40±11.08	Moderately Clean	4.83±0.24	0.2106±0.0635
DECTAR (Near Road)	(-5.83)±7.94	Polluted	4.81±0.56	0.2065±0.0192
UKM Round About	(-5.69)±3.17	Polluted	4.78±0.33	0.6472±0.1480
Chancellory	(-6.58)±2.02	Polluted	4.74±0.07	0.5555±0.0699
Danau UKM	16.93±8.93	Clean	4.49±0.07	0.7831±0.1916
Education Faculty	3.90±7.52	Moderately Clean	5.69±0.71	0.7832±0.0555
Economy and Business Faculty	19.83±2.08	Clean	4.59±0.33	0.4733±0.1430
Rahim Kajai College	12.58±15.96	Clean	4.65±0.26	0.6709±0.1434
Tun Abdullah Mat Salleh Complex	0.67±1.66	Moderately Clean	6.21±0.06	1.0658±0.2930
Information Technology Centre	11.75±6.81	Clean	5.24±0.13	1.1329±0.2191
Engineering Faculty	24.17±2.02	Clean	5.86±0.35	0.8501±0.4010
Information Science and Technology Faculty	27.17±5.01	Clean	5.85±0.09	1.2709±0.2734

Based on Table 3, the highest score for air quality is at the Green House while the lowest is -7.83 at Aman Building. The highest pH value is 6.21 at Tun Abdullah Mat Salleh Complex while the lowest pH is 4.41 at the Chemistry Building FST and Aminuddin Baki College. For the nitrogen content, the highest value is 1.2709 % at the Information Science and Technology Faculty and the lowest nitrogen content is 0.1554 % at the Green House. Two types of graph was plotted based on Table 3, i.e. Air Quality Score versus pH value and nitrogen content value, Air and pH value versus nitrogen content.

The areas around Aman Building, UKM Mosque (Middle section), Aminuddin Baki College, Ungku Omar College, UKM Round about, Chancellory, DECTAR (Next to road) and UKM mosque (next to road) are all near to the main road which is the main source of pollution. The main road is the common route for all vehicles entering and leaving the campus especially during the rush hour in the morning, lunch break and the rush hour in the evening between 5.00 and 6.00 pm. Emissions from vehicles release air pollutants especially nitrogen dioxide gases, carbon monoxide, PAH and heavy metals such as, Pb, Zn, Cu and Ni. Most of the lichen species growing in these areas are the species with high tolerance such as *Hyperphyscia adglutinata* and *Pyxine cocoes*. Other species observed are *Dirinaria picta, Lecanora helva, Trypethelium elutteria, Lecanographa* and *Parmotrema praesorediosum* (low frequency).

The areas in front of DECTAR, Chemistry Building FST, and Biocompatibility Laboratory, the gate to Outer Ring Road 2, Ibrahim Yaakub College, Education Faculty and Tun Abdullah Mat Salleh Complex are located in the category of Moderately Clean Air. Despite the fact that these areas are next to the road, the air quality is not as polluted as the previous areas. This is because the roads are not the main road for the vehicles in the campus. Only road users specific to the buildings use the roads. Thus the amounts of emission from vehicles are at a safe level because it is far from the main road. Among the species found in these areas are *Pyxine Cocoes, Lecanora Helva, Dirinaria picta, Chrysothrix xanthina, Parmotrema* dan *Physcia*.

For areas categorized as clean air, 12 areas are identified. These areas are far from the main road and fewer vehicles drive past through. The areas are Danau UKM, Nuclear Science Building, Information Technology Centre, Faculty of Information Science and Technology, and 3 areas around the Green House. There are also Areas next to the main road such as Faculty of Economy and Business, Rahim Kajai College, Engineering Faculty and UKM Mosque (Front Section) which is categorized as clean air. This is attributed to the fact that the palm trees in these areas are young trees and not matured enough. Various species of lichens which are in the group of sensitive and moderate lichens are found in these regions such as *Physcia*, *Parmotrema*, *Dirinaria picta*, *Chrysothrix xanthina, Trypethelium, Laurera, Caloplaca* and *Lecanora helva*. Species from the tolerant species are also found but in a very low frequency.

Figure 1 shows the Air quality Score plotted against pH values and nitrogen content. The pH of the bark at each area is not uniform. In polluted areas, there are barks with high pH values as well as low pH values. The same can be observed for the moderately clean and clean areas where the tree bars show both high and low pH values. The two triangular diagrams in Figure1 show clear differences between Air Quality Scores and the pH values. Nitrogen content percentage also shows values which are not uniform. Nevertheless, the linear line obtained showed that the higher the percentage of nitrogen, the higher the Air Quality Score, especially for the case of negative scores compared to the positive scores. Other factors influence the values such as the species of the trees are different, leading to differences in the pH values as in Table 3 (Brodo, 1961; Orange, 1994; Wolseley & Pryor, 1999). Other factors which influence the experimental results may be due to the direction at which the bark was taken (Young, 1938) and the height of the sample taken (Hale, 1967) as well as the distance of the tree from the source of pollution at UKM which is the road.

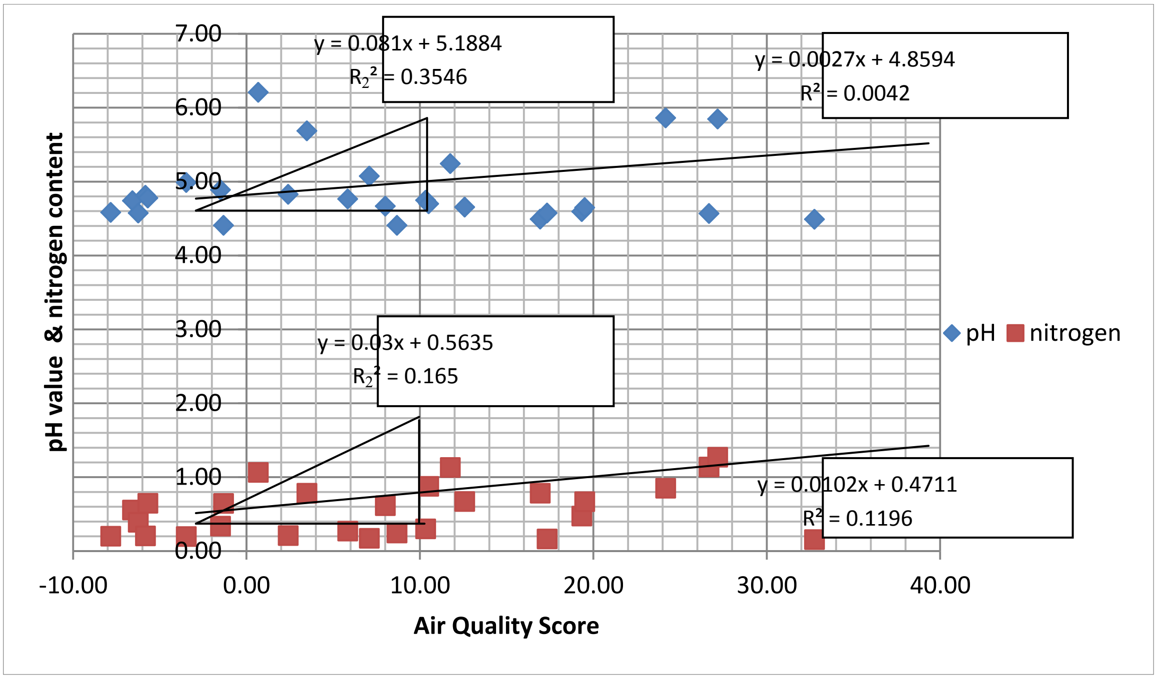

Figure 1. Air Quality Score versus pH value and nitrogen content

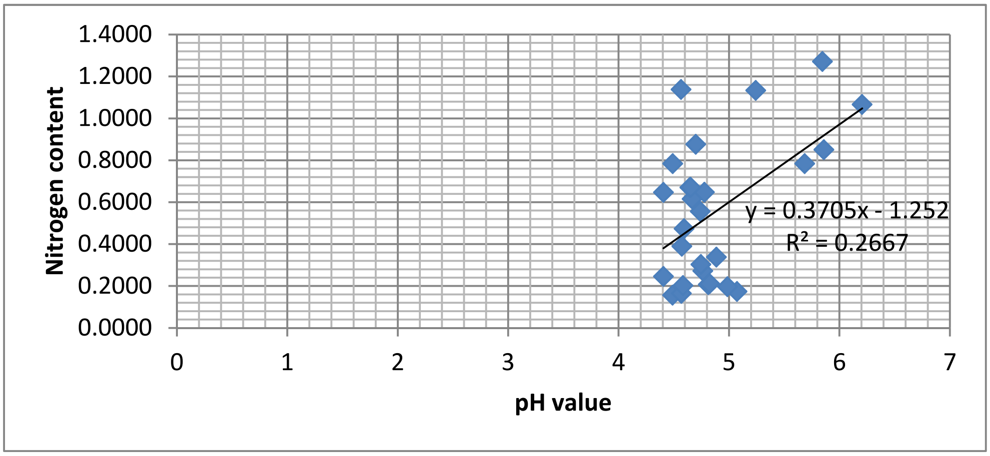

Figure 2. pH values vs nitrogen content

From Figure 2, the graph shows linear relationship between the nitrogen content towards the hydrogen ion concentration (pH) of the bark of the tree. Overall the high percentage of nitrogen content will increase the pH value of the bark which in turn will increase the air quality score at the tree. This variation is clearly observed at high pH values which are bordered with nitrogen content of more than 0.8 percent. These results are consistent with previous workers as the rise in nitrogen content at the tree bark will raise the pH value of the particular tree bark (Barkman, 1958; Gilbert, 1976; van Herk, 2001; Katz, 1961).

The spatial interpolation of the Air Quality Score is shown in the map depicted in Figure 3. With this map, it is possible to locate the most disturbed zone in the studied area. The areas with the greatest disturbance were located parallel to the road which is heavy traffic movement.

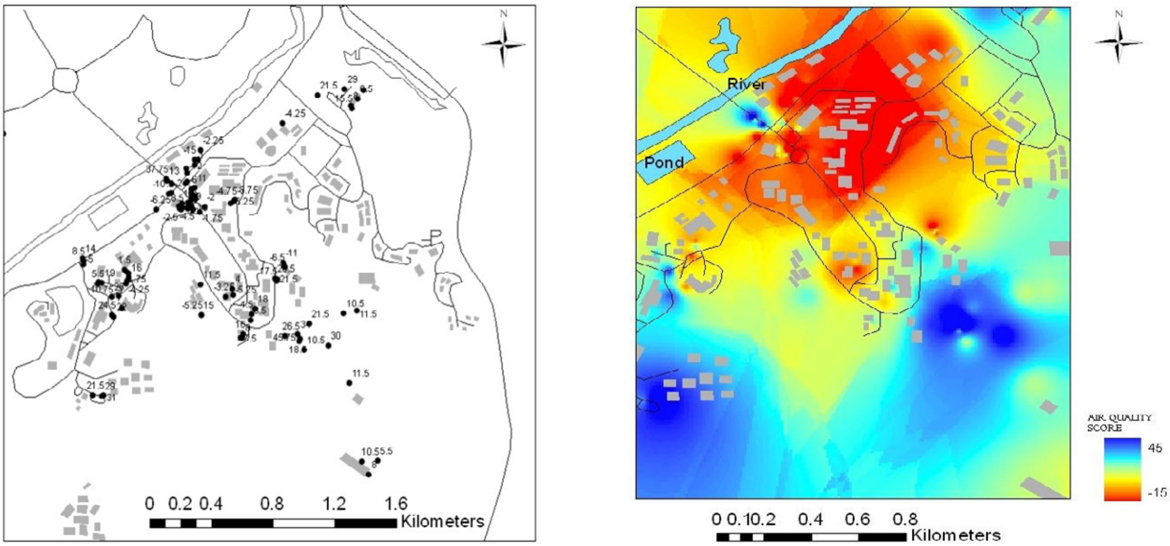

Figure 3. Plot of Air Quality Score on the UKM map

4. Conclusion

The air quality score in UKM is 8.39±11.64. The mean pH value for bark of the palm trees hosting the lichens is 4.88±0.48 and the mean nitrogen content of the tree barks is 0.5567±0.3431%. Overall, 27 areas of study can be divided to three groups, which is polluted area, moderately clean areas and clean areas. The overall air quality at the UKM campus is moderately clean. However, monitoring and control are required to rescue the effect of pollutants to create an environment of clean air at the University campus. The study involves multidisciplinary researchers in the field of chemistry, botany, geography, mathematics, education, environment and the public at large.

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