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Estimation of Two Species of Urban Plants for Airborne Particulates Deposition: The Influences of Meteorological Parameters and Pollutants Sources

Anggaran Dua Spesies Tumbuhan Bandar untuk Pemendapan Zarah *Airborne*: Pengaruh Parameter Meteorologi dan Sumber Pencemar

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ABSTRACT

In spite of being a part of the urban green infrastructures, urban forest is able to ameliorate the urban atmosphere through the deposition of particulates deposition on the surfaces of vegetations. The deposition is aided by the several factors such as boundary layer that exists on the surfaces of plants; the morphological characteristics as well as the meteorological parameters such as wind speeds, rainfall and mean temperature. This paper discusses on the role of urban plants (Ficus microcarpa and Acalypha siamensis) in capturing the airborne pollutants from various sources on the leaves surfaces. The findings showed that the elements' concentration was greatly influenced by the meteorological parameters. Ca increases with the increased of wind speed (r = 0.702) at Jalan Hang Tuah, whereas at Country Heights Kajang, Mg was correlated to mean temperature (r = 0.795) and rainfall (r = 0.732); K, Cu, Th and PM were correlated to wind speed (r = 0.703, 0.777, 0.735 and 0.689 respectively); Rb and W were correlated to minimum temperature (r = 0.669 and r = 0.783 respectively) while Mn, W and PM were highly correlated to relative humidity (r = 0.839; r = 0.755) and r = 0.680 respectively). The meteorological parameters influence the deposition of pollutants is also due to the sites background and pollutants sources. The results also showed the elements with their possible sources; Country Heights Kajang: K and Ca (7.898%) were originated from construction while Sc, Ni, Cr, Ti and S (17.592%) were mainly emitted from sediments or road dust along Jalan Hang Tuah. Therefore, sustainability for good quality of urban air is achieved through the planting of more vegetation in urban areas.

Keywords: Urban plants; meteorological parameter; pollutants

ABSTRAK

Walaupun menjadi sebahagian daripada infrastruktur bandar hijau, hutan bandar dapat memperbaiki suasana bandar melalui endapan partikel pemendapan pada permukaan tumbuh-tumbuhan. Pemendapan ini dibantu oleh beberapa faktor seperti lapisan sempadan yang wujud pada permukaan tumbuhan; ciri-ciri morfologi dan juga parameter meteorologi seperti kelajuan angin, hujan dan min suhu. Kertas kerja ini membincangkan mengenai peranan tumbuhan bandar (Ficus microcarpa dan Acalypha siamensis) dalam menangkap pencemar udara daripada pelbagai sumber pada permukaan daun. Dapatan kajian menunjukkan bahawa kepekatan unsur-unsur 'telah banyak dipengaruhi oleh parameter meteorologi. Ca meningkat dengan peningkatan kelajuan angin (r = 0,702) di Jalan Hang Tuah, manakala di Country Heights Kajang, Mg telah dikaitkan dengan min suhu (r = 0,795) dan hujan (r = 0,732); K, Cu, Th dan PM telah dikaitkan dengan kelajuan angin (r = 0,703, 0,777, masing-masing 0,735 dan 0,689); Rb dan W telah dikaitkan dengan suhu minimum (r = 0,669 dan r = 0,783 masing-masing) manakala Mn, W dan PM telah berkait rapat dengan kelembapan relatif (r = 0,839; r = 0,755) dan masing-masing r = 0,680). Parameter meteorologi mempengaruhi pemendapan bahan pencemar juga disebabkan oleh sumber-sumber latar belakang laman dan bahan pencemar. Keputusan juga menunjukkan unsur-unsur dengan punca-punca mereka; Country Heights Kajang: K dan Ca (7,898%) telah berasal daripada pembinaan manakala Sc, Ni, Cr, Ti dan S (17,592%) didapati daripada sedimen atau debu jalan di Jalan Hang Tuah. Oleh itu, kemampanan udara bandar untuk kualiti yang baik dicapai melalui penanaman lebih tumbuh-tumbuhan di kawasan bandar.

Kata kunci: Tumbuhan bandar; parameter meteorologi; pencemaran

INTRODUCTION

The issues of air pollution occurrence has long been acknowledged and become an attention worldwide. There are many factors that contribute to the occurrence of air pollution which include the increase of population growth (high birthrate), bloom of industrial activities and high pace development of transportation sector (Hopke et al. 2008; Nur Dina et al. 2012).

Besides of the human-induced activities, the natural disasters such as volcanic eruptions and forest fire are also the air pollution contributors. Malaysia is one of the countries which once had been affected by the serious air pollution during 1997 due to the vigorous economic activities and transboundary dispersion of airborne pollutants from Indonesia. Furthermore, the major contributor to the contaminated urban air quality is the automobiles emission (Mohd. Azam et al. 2012; Afroz et al. 2003).

Awang et al. (2000) reported that there are none of the monitored sites in Kuala Lumpur are free from dust pollution at all times. Based on finding of many literatures, various types of pollutants continued to present in the highest concentration mainly at the central district of Kuala Lumpur. The airborne pollutants give detrimental impacts on the atmospheric environment of urban areas, the ecosystems functions as well as the health of the residents. Moreover, the pollutants could elevate and raise the temperature and microclimate of the region and worsening the ozone layer promoting to the climate change. These could adversely affect the tourism sector of a country which leads to the inflation in economic sector.

In order to achieve the aim of being an industrialized and developed country by the year 2020, many trees and plants have been cut off to give way to the constructions and other developmental projects resulting into the increase of urban heat island, disturbance of biodiversity of flora and fauna, and other environmental degradations (Azmi et al. 2010). It has been concerned that the anthropogenic activities especially the road transportation and the industrial activities have became the major sources of air pollution in megacities worldwide (Shan et al. 2007; Bealey et al. 2007). These sources emit particulates matter and other harmful chemical elements such as oxides of Nitrogen (NO_x), Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Lead (Pb) that exacerbates the atmosphere condition.

In order to mitigate the air pollution, one of the best implementation is by planting more trees and other vegetations in the urban areas as plants are the significant pollutant scavengers. Plants are highly exposed to the polluted environment in the urban areas. Most of the planted urban plants are highly tolerate to the harsh environment, less-tailored and could maintain healthy growth unless they are being exposed to severe haze or high contaminated areas (Ainuddin & NurNajwa 2009). The examples of tolerant species of urban trees in Kuala Lumpur, Malaysia are the Red Flame (*Poncianaregia*) and the Rain Tree (*Samaneasaman*) which could be a great filter to the airborne pollutants (Justice 1986). Generally, all the plant parts such as the leaves, twigs, trunk, branches and even petiole are highly exposed to the atmospheric layer which enables them to filter great amounts of airborne pollutants very effectively (Beckett et al. 2000; Brack 2000; Chakre 2006; Givoni 1991; McDonald 2001; Mulgrew 2000 & Nowak 2006). Shan et al. (2007) found that the most contaminated space is located below 1.7 meters in height and within 50 meters on both sides along the main road where this space is commonly being occupied by the plants and living ecosystem as well. This is also the area in which the respiration of human and other creatures takes place and thus could threaten their health. Therefore, the presence of plants in a city, specifically within this range, could significantly reduce the amount of airborne pollutants.

METHODOLOGY

DESCRIPTION OF STUDY AREA

The main criteria for a site to be selected are plant availability, road access and presence of air quality monitoring stations. According to Shan et al. (2007), the most contaminated area is located within 2 meters in heights and 50 meters on both sides along the main road. Thus, the chosen study sites were based on these characteristics to gain best results. Two locations selected for this study were:

1. Klang Valley (urban settlement):
    a. Jalan Hang Tuah, Kuala Lumpur; and
2. Selangor (residential area):
    b. Country Heights, Kajang

Jalan Hang Tuah, Kuala Lumpur (lat:3°8’17”;lng:101°42’18”) was selected as one of the study sites due to its characteristics as an urban area. It is one of the places that is situated in the center of Kuala Lumpur which comprises three-lanes roads on both sides where there are numbers of tall buildings, mosque, car parks, constructions and Light Railway Transit station available in this area. This reflects that this place is having poor atmospheric condition due to the frequent traffic congestion. Being part of the Klang Valley, Jalan Hang Tuah experiences a tropical climate with annual southwest monsoon starting from April to October and northeast monsoon from October to February.

Another chosen site was Country Heights Kajang, Selangor (lat: 2° 59’ 6”; lng: 101° 44’ 51”) which is a luxurious residential area surrounded by a well-landscape environment with peaceful greenery space. There are multiple plant species planted in this area especially on road dividers, roundabouts, roadsides, entrances and surrounding the villas such as *Cordylinefruticosa* ‘Firebrans’, *Hymenocalliscaribaea* ‘Spider Lily’ and *Alternanthera* red.

FIGURE 1. Map of the study site for Jalan Hang Tuah, Kuala Lumpur

Source: https://maps.google.com.my

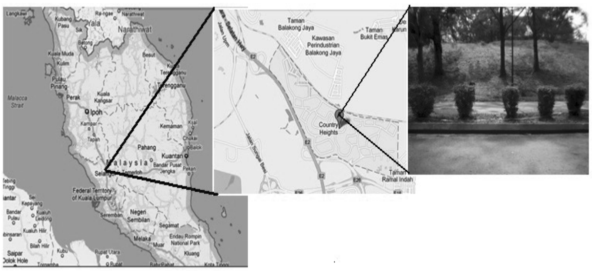

FIGURE 2. Map of the study site for Country Heights, Kajang, Selangor

Source: https://maps.google.com.my

SELECTION OF APPROPRIATE PLANT SPECIES

Since the contaminated area is within 2 meters in heights and 50 meters in widths of a main road, a plant species that distributed within this area were being selected. Thus, plant with less than 2 meters in heights was given a priority for a selection at both study sites. The important characteristics of a selected plant species are healthy plant that free or less affected from diseases, have a dense crown volume, broad leaf size, evergreen and large number of leaf per crown in order to give best effects. Therefore, based on the characteristics above, *Ficusmicrocarpa* L. f. and *Acalyphasiamensis* Oliv. ex Gage were the most suitable plant species and selected at Jalan Hang Tuah Kuala Lumpur and Country Heights Kajang respectively.

FIGURE 3. *Ficusmicrocarpa* L. f. (left) and *Acalyphasiamensis* Oliv. ex Gage (right)

SAMPLE COLLECTION

Materials The tools used for this research were the Whatman Cyclopore Track Etched Membrane 7060-4714 (47 mm 8 μm), 500 Sterilized-Disposable Plastic Petri Dishes [FAVORIT ®], 34 mm of nylon paint brush and tagging tape.

METHODS

Three plants were chosen for each plant species at each study site. For every single plant of both species, four leaves were selected randomly. The adaxial surface of those selected leaves was lightly scrubbed by using no-hair-loss 34 mm of paint brush for about 20-30 seconds, tagged and left exposed to the air for 24, 48 and 72 hours. There were 3 replications for each period of exposure respectively. After the exposures, the leaves were lightly scrubbed using a clean paint brush for about 20-30 seconds to gather all the dusts present and deposited onto a Cyclopore Track Etched Membrane filter. The filters were then inserted into Sterilized-Disposable Plastic Petri Dishes [FAVORIT ®], tightly closed, sealed and brought to the lab for analyses.

METEOROLOGICAL DATA COLLECTION

Hourly basis data for rain distribution, wind speed and direction, temperature and relative humidity of both study sites were obtained from Alam Sekitar Malaysia Sdn Bhd (ASMA) and Department of Environment (DOE); February and March 2011 for Country Heights, Kajang whereas March and April 2011 for Jalan Hang Tuah, Kuala Lumpur. These periods represented the study period taken for this project.

STATISTICAL ANALYSES

The statistical software used was IBM SPSS Statistics 20, WRPLOT of Lakes Environment and basic Microsoft Office Excel 2007. Pearson correlation analysis was done to see the relationship among variables namely elements, the meteorological parameters and the sites. A simple radar graph was done to determine the direction of elements blown by which based on the wind direction provided by DOE. Besides, Principle Component Analysis (PCA) and the Enrichment Factor (EF) were conducted to determine the possible sources or source apportionment of each elements present. For PCA, Varimax with Kaiser Normalization was applied as rotated component matrix with Eigenvalues greater than 1 while for the EF, the amount or ratio of the sample element, enrichment above the concentration present in the reference station material of the earth crusts was referred to anthropogenic sources (Taylor 1964; Olubunmi and Olorunsula 2010). The formula used for EF calculation was adopted from Lee et al. (1994) and shown as below:

$$\frac{\text{Concentration of element X in sample} \div \text{concentration of reference element in sample}}{\text{Concentration of element X in Earth's crust} \div \text{concentration of element in Earth's crust}}$$

where, the concentration of the Earth's crust was referred to Taylor (1964).

RESULTS AND DISCUSSION

THE METEROLOGICAL PARAMETERS ANALYSES OF STUDY SITES

The trends of wind speeds, wind directions and rain distributions of both study sites throughout the study periods were presented in a simple bar graph and wind rose using WRPLOT as shown in Figure 4 to 7. Country Heights Kajang experienced highest dry records (55.6%) followed by 25.9% precipitation intensity of ≥ 4.0 mm/hr during the study period; February 9 to March 7, 2011. This area was having hot and humid condition with relative humidity ranging from 71-80% throughout the sampling period. Even though the Northeast monsoon was occurring during the sampling period, this site however was slightly affected by the monsoon. This is because, the areas on the east side of Peninsular Malaysia such as Kelantan, Pahang and Terengganu were only affected seriously by heavy rainfall during this monsoon.

The rain was mainly distributed among the East and South regions of Country Heights Kajang especially East South East (ESE) and South East (SE) areas. This could possibly due to the wind speed which blown together with the rainfall (Figure 5). The wind speed was almost at calms rate which was at 0.5-1.5 m/s reflecting that this residential area was having steady and calm condition. Moreover, there were many plants surrounding the houses as well as along the roads, ranging from smaller shrubs to the taller trees which helped to slow down the wind turbulence significantly (Syngellakis and Traylor 2007).

In contrast, Jalan Hang Tuah, Kuala Lumpur was having greater wind speed and frequent rainfall during the study period; March 13 to April 2, 2011. Figure 6 shows that this site was likely experiencing a balance rainfall distribution, which mean that the percentage of dry records was almost equal to the highest precipitation intensity (≥ 4.0 mm/hr); 38.1% and 33.3% respectively. The relative humidity recorded by this area throughout the sampling period was ranged from 57-83%. The rainfall was distributed most from the North North East (NNE), South and South West (SW) regions which were mainly due to the direction of wind speed as shown in Figure 7 where the dominant wind speed was blowing from the West and West South West (WSW) to this area. This could possibly happen due to the inter monsoon period that usually occurred from March to May before the Southwest Monsoon (May to September) takes place. Jalan Hang Tuah was having different weather condition compared to Country Heights Kajang possibly due to the higher vehicles speed during the non-rush hours (Leong et al. 2002). Moreover, air dispersion in a street canyon is different from that in a flat open space (Taseiko et al. 2009). Contaminated atmosphere condition could be the possible cause of the alteration of microclimate in this urban area (Nowak 2000).

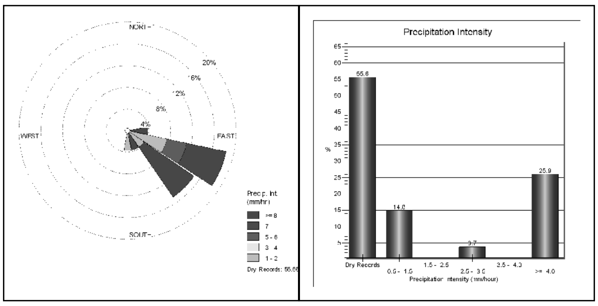

FIGURE 4. Wind rose of rain precipitation (left) and percentage of precipitation intensity, mm/hour (right) of Country Heights, Kajang from February 9 to March 7, 2011.

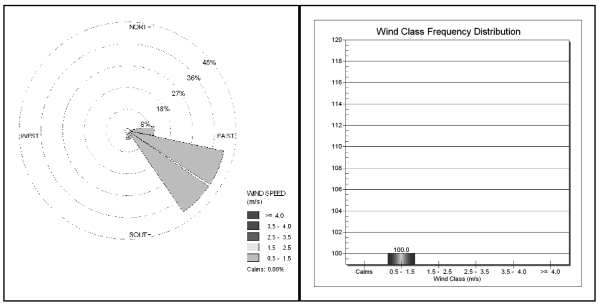

FIGURE 5. Wind rose of wind speed (left) and frequency of wind class distribution, m/s (right) of Country Heights, Kajang from February 9 to March 7, 2011.

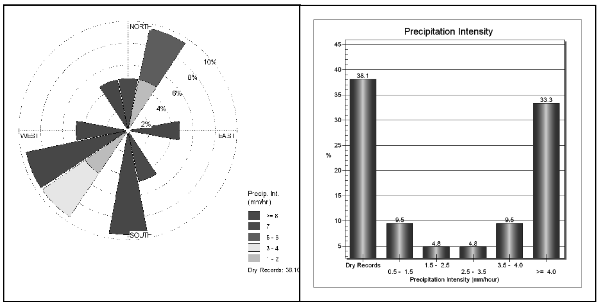

FIGURE 6. Wind rose of rain precipitation (left) and percentage of precipitation intensity, mm/hour (right) of Jalan Hang Tuah, Kuala Lumpur from March 13 to April 2, 2011.

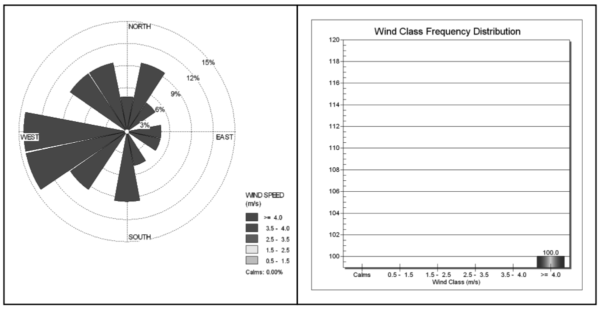

FIGURE 7. Wind rose of wind speed (left) and frequency of wind class distribution, m/s (right) of Jalan Hang Tuah, Kuala Lumpur from March 13 to April 2, 2011.

METEOROLOGICAL PARAMETERS INFLUENCE DEPOSITION OF AIRBORNE POLLUTANTS

Meteorological can influence the dispersion of airborne pollutants especially particulate matters. Figures 8 and 9 show the trend of the elements and particulate matter that due to the meteorological effects. According to Wrobel et al. (1999), the elemental concentration of coarse size fraction especially particulate matter within an area is strongly depended on the meteorological parameters such as the rainfall, wind speed, temperature and relative humidity. Therefore, due to the Northeast monsoon which occurred during the sampling days in Country Heights Kajang and Intermonsoon period at Jalan Hang Tuah Kuala Lumpur, the elemental concentrations fluctuated significantly through the days regardless of the increase of the sampling periods.

In fact, some of the elements were chemically inactive and stable such as Si, Na, and Al which could remain longer in the atmosphere especially on the leaves surfaces. However, some of the elements that originated from the anthropogenic sources such as W, As, Mg, K, Cu, Ba, PM and Zn would undergo chemical reactions in the atmosphere or been washed away by the rainfall and wind speed as well as been volatilized during higher temperature. Based on the results of both sites, it can be concluded that the concentration of all elements that deposited on the leaves surfaces was greatly influenced by the meteorological parameters. Wrobel et al. (1999) found that the concentration of elements tends to increase or decrease concurrently with the changes of the meteorological parameters. For instance, Givoni (1991) stated that the fine particles will be swept away by the wind while the large particles are trapped by the dense foliage.

The trends of elements' concentration due to wind speed are shown in Figures 10 and 11. It shows that some of the elements were negatively correlated with the wind speed such as PM, indicating that the concentration was decreased with the increasing of wind speed due to the dispersion of elements. However, some of the elements (such as Sb) could retain on the leaf surface even though during windy condition. This is because, the deposition of particles on the leaf surface is aided by the inertia forces and wind speed that make the particles enable to go through the boundary layer and onto the surface (Beckett et al. 2000). The higher the wind speed, the greater the forces and gives better impaction of particles on the leaf surface. In addition, relative humidity that is greater than 55% could have greater effects on the concentration of PM_{10} in the atmosphere (Ul-Saufie et al. 2011). This could possibly due to the ability of the elements to retain longer in a condensed and humid atmosphere. As a result, the concentration of PM was slightly increased with the increased of the percentage of relative humidity (Figures 8 and 9). Moreover, the increased of rainfall resulted into the declining of PM and some of the elements' concentration as shown in Figures 8 and 9.

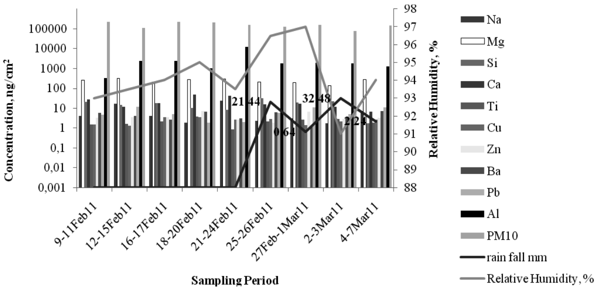

FIGURE 8. The impact of rainfall and relative humidity on the selected elements and PM_{10} at Country Heights Kajang.

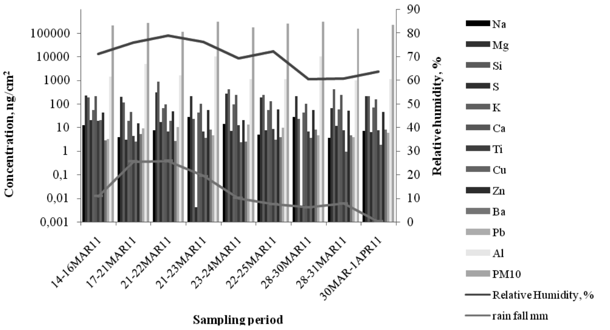

FIGURE 9. The impact of rainfall and relative humidity towards the selected elements and PM_{10} at Jalan Hang Tuah Kuala Lumpur

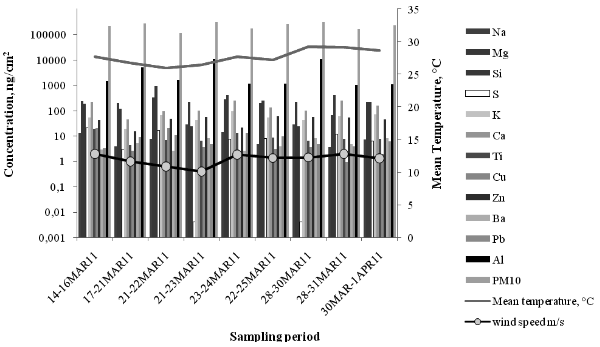

FIGURE 10. The impact of mean temperature and wind speed towards the selected elements and PM_{10} at Jalan Hang Tuah Kuala Lumpur

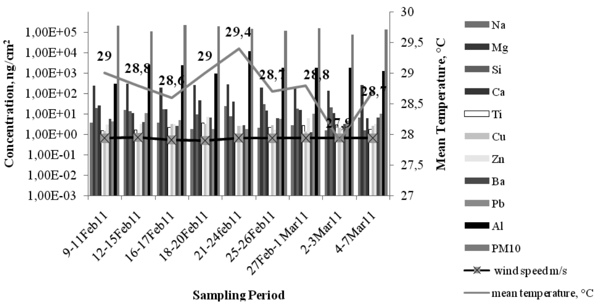

FIGURE 11. The impact of mean temperature and wind speed on selected elements and PM at Country Heights Kajang

The relationship between the meteorological parameters and the airborne pollutants was analyzed using Pearson Correlation analysis as shown in Table 1 and 2. The result of Jalan Hang Tuah Kuala Lumpur shows that only Ca was significant at 95% confidence interval (r = 0.702) with the wind speed indicating that the concentration of Ca was increased with the increased of wind speed. Ca was highly correlated with the wind speed at r = 0.85 (Table 1). Ca is a natural element which originated from wind-blown dust (Lee et al. 1999; Schmitt and Stille 2005) and could mobilize easily in the atmosphere due to relatively weakly bonded to soil colloids (Chadwick et al. 1999). Therefore, it was easily being transported by the movement of vehicles' tyre or wind onto the leaf surface. The other elements however, had weak correlation with the wind speed possibly due to the effects of other meteorological parameters and complicated urban conditions.

Unlike Jalan Hang Tuah Kuala Lumpur, there were eight elements deposited which were highly correlated to the meteorological parameters at Country Heights Kajang as shown in Table 2. Mg was correlated to mean temperature at 95% confidence interval (r = 0.795) and rainfall (r = 0.732) while

K, Cu, Th and PM were correlated to wind speed (r = 0.703, 0.777, 0.735 and 0.689 respectively). Rb and W were correlated with minimum temperature at 95% at r = 0.669 and r = 0.783 respectively while Mn was highly correlated to relative humidity at 99% (r = 0.839) followed by W (r = 0.755) and PM (r = 0.680) at 95% significant difference.The difference of the results of both sites was likely due to the different types of site's characteristics where Jalan Hang Tuah was more urbanized with higher traffic density than Country Heights Kajang which was only a residential area. Previously, it has been discussed that Country Heights Kajang was experiencing higher relative humidity and lower mean temperature and wind speed as compared to Jalan Hang Tuah Kuala Lumpur. Therefore, this indicates that those elements were able to retain slightly longer on the leaf surface of *A. siamensis* as the meteorological condition was mild compared to Jalan Hang Tuah Kuala Lumpur.

TABLE 1. Pearson correlation analysis of meteorological parameters and the elemental concentration at Jalan Hang Tuah Kuala Lumpur (*F. microcarpa*)

		Na	Mg	Si	S	K	Ca	Sc	Ti
Sampling period	Pearson Correlation	-.023	-.465	-.088	-.364	.349	.263	-.520	-.344
	Sig. (2-tailed)	.953	.208	.821	.336	.357	.494	.152	.365
Relative Humidity, %	Pearson Correlation	-.094	.560	.293	.174	-.235	-.485	.053	-.048
	Sig. (2-tailed)	.809	.117	.445	.655	.543	.186	.892	.902
Mean Temperature	Pearson Correlation	.068	-.570	-.335	-.123	.186	.497	.051	.122
	Sig. (2-tailed)	.861	.109	.379	.753	.632	.173	.897	.754
Wind speed, m/s	Pearson Correlation	-.350	-.358	-.053	.334	.353	.702*	.389	.540
	Sig. (2-tailed)	.356	.344	.892	.379	.352	.035	.301	.134
Rainfall, mm	Pearson Correlation	-.031	.368	.312	.061	-.445	-.564	-.095	-.301
	Sig. (2-tailed)	.937	.330	.414	.877	.230	.114	.807	.431
		V	Mn	Co	Cu	Zn	As	Rb	Sb
Sampling period	Pearson Correlation	-.586	-.046	-.179	-.658	.435	-.582	-.280	.598
	Sig. (2-tailed)	.097	.907	.645	.054	.242	.100	.465	.089
Relative Humidity, %	Pearson Correlation	.317	.029	.090	.465	-.264	.148	.104	-.495
	Sig. (2-tailed)	.406	.942	.818	.208	.493	.705	.790	.176
Mean Temperature	Pearson Correlation	-.240	-.031	-.022	-.415	.210	-.048	-.061	.436
	Sig. (2-tailed)	.533	.937	.956	.267	.588	.902	.876	.240
Wind speed, m/s	Pearson Correlation	-.027	-.477	.469	-.098	-.159	.443	-.147	.330
	Sig. (2-tailed)	.945	.194	.202	.801	.683	.232	.705	.386
Rainfall, mm	Pearson Correlation	.547	.044	-.146	.374	-.362	.203	.395	-.478
	Sig. (2-tailed)	.128	.910	.708	.321	.338	.601	.293	.193
		Ba	Ce	Sm	W	Pb	Th	Al	PM
Sampling period	Pearson Correlation	.511	.220	.241	.004	-.145	.330	-.051	.037
	Sig. (2-tailed)	.159	.569	.533	.992	.710	.386	.897	.925
Relative Humidity, %	Pearson Correlation	-.390	.023	-.019	-.011	.438	-.351	.001	-.093
	Sig. (2-tailed)	.300	.953	.962	.978	.238	.354	.999	.811
Mean Temperature	Pearson Correlation	.357	-.063	-.041	.000	-.482	.370	-.021	.112
	Sig. (2-tailed)	.346	.872	.917	1.000	.188	.327	.957	.775
Wind speed, m/s	Pearson Correlation	-.322	.035	-.430	-.581	-.079	.585	-.530	-.222
	Sig. (2-tailed)	.398	.929	.248	.101	.841	.098	.142	.565
Rainfall, mm	Pearson Correlation	-.294	-.057	-.139	.153	.317	-.374	.210	-.129
	Sig. (2-tailed)	.442	.884	.722	.695	.407	.321	.588	.741

* Correlation is significant at the 0.05 level (2-tailed).

TABLE 2. Pearson correlation analysis of meteorological parameters and the elemental concentration at Country Heights Kajang (*A. siamensis*)

		Na	Mg	Si	K	Ca	Sc	Ti	V
Day of sampling	Pearson Correlation	-.195	-.459	-.125	-.178	-.374	.349	.234	-.527
	Sig. (2-tailed)	.614	.214	.749	.646	.322	.357	.545	.145
Relative Humidity	Pearson Correlation	-.206	.067	.203	.231	.065	-.185	.189	-.037
	Sig. (2-tailed)	.595	.863	.600	.550	.869	.633	.625	.924
Maximum Temperature	Pearson Correlation	.561	.589	.140	.131	.339	-.003	-.510	-.097
	Sig. (2-tailed)	.116	.095	.719	.737	.372	.993	.161	.804
Minimum Temperature	Pearson Correlation	.181	.422	-.615	.260	.520	-.092	-.070	.063
	Sig. (2-tailed)	.641	.258	.078	.499	.152	.815	.859	.872
mean temperature	Pearson Correlation	.577	.795*	-.381	.305	.660	-.072	-.452	-.054
	Sig. (2-tailed)	.104	.010	.312	.425	.053	.855	.222	.890
wind speed, ms	Pearson Correlation	.416	-.029	.131	-.703*	-.513	.347	-.572	-.317
	Sig. (2-tailed)	.266	.940	.737	.035	.158	.360	.107	.406
Rainfall, mm	Pearson Correlation	-.375	-.732*	.590	-.192	-.375	.412	.286	-.216
	Sig. (2-tailed)	.320	.025	.095	.621	.320	.271	.456	.577

		Mn	Co	Cu	Zn	As	Rb	Sb	Ba
Day of sampling	Pearson Correlation	.066	.057	.149	-.030	-.280	.239	-.272	.000
	Sig. (2-tailed)	.866	.884	.703	.938	.465	.536	.478	1.000
Relative Humidity	Pearson Correlation	-.839**	.307	.109	.405	-.086	.008	-.206	.000
	Sig. (2-tailed)	.005	.422	.779	.279	.826	.984	.596	1.000
Maximum Temperature	Pearson Correlation	-.179	.415	.021	-.344	-.029	-.493	.592	.264
	Sig. (2-tailed)	.644	.267	.957	.365	.940	.178	.093	.492
Minimum Temperature	Pearson Correlation	-.541	.176	.067	.597	-.264	.669*	-.047	-.156
	Sig. (2-tailed)	.132	.650	.864	.090	.492	.049	.904	.689
Mean Temperature	Pearson Correlation	-.549	.449	.052	.199	-.256	.130	.426	.102
	Sig. (2-tailed)	.126	.226	.894	.608	.506	.739	.253	.795
Wind Speed, Ms	Pearson Correlation	.108	-.088	-.777*	-.484	-.358	-.511	.353	-.234
	Sig. (2-tailed)	.782	.823	.014	.186	.345	.159	.352	.545
Rainfall, mm	Pearson Correlation	.568	.085	.037	-.439	.157	-.435	.088	.046
	Sig. (2-tailed)	.111	.827	.924	.237	.688	.242	.823	.907

		Ce	Sm	W	Pb	Th	Al	PM
Day of sampling	Pearson Correlation	.288	-.222	.166	.229	.108	.022	-.549
	Sig. (2-tailed)	.452	.565	.670	.553	.781	.955	.126
Relative Humidity	Pearson Correlation	-.078	-.215	.092	.229	.057	-.115	.240
	Sig. (2-tailed)	.842	.578	.813	.553	.884	.768	.534
Maximum Temperature	Pearson Correlation	.402	-.588	.189	-.192	.532	.467	-.070
	Sig. (2-tailed)	.283	.096	.626	.620	.141	.205	.858
Minimum Temperature	Pearson Correlation	-.103	.148	-.783*	-.120	-.240	.208	.722*
	Sig. (2-tailed)	.793	.703	.013	.759	.534	.592	.028
Mean Temperature	Pearson Correlation	.250	-.340	-.472	-.228	.249	.514	.494
	Sig. (2-tailed)	.516	.371	.200	.556	.518	.157	.177
Wind Speed, Ms	Pearson Correlation	.102	.001	-.146	.551	.735*	.211	-.689*
	Sig. (2-tailed)	.794	.999	.708	.124	.024	.586	.040
Rainfall, mm	Pearson Correlation	.198	-.308	.755*	-.124	-.053	-.163	-.680*
	Sig. (2-tailed)	.610	.420	.019	.750	.893	.675	.044

**. Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Wind direction and wind speed are the meteorological parameters which give significant influences on the dispersion of the atmospheric pollutants. The wind might blow together with the elements from particular sources into the study sites. Figure 12 shows the dispersion pattern of selected elements in Country Heights Kajang which summarizing the direction of elements blown from, between the South East (SE) and East South East (ESE). In contrast, dissimilar directions of pollutants dispersion were found at Jalan Hang Tuah Kuala Lumpur as shown in Figure 13, where elements were blown from North East (NE), North North East (NNE), South (S), South South West (SSW), South West (SW), West South West (WSW), West North West (WNW) and North West (NW). Air dispersion in urban area is different from that in rural background or residential area (Taseiko et al. 2009). Therefore, the dispersion of pollutants is varying according to the types of location. Moreover, the availability of the natural and anthropogenic sources in the study sites is also one of the factors that affecting the dispersion of the airborne pollutants. The urban site of Kuala Lumpur is known to have various types of industries as well as higher traffic density compared to a residential area of Country Heights Kajang. This shows that the dispersion of pollutants was likely emerged from various directions surrounding the study sites.

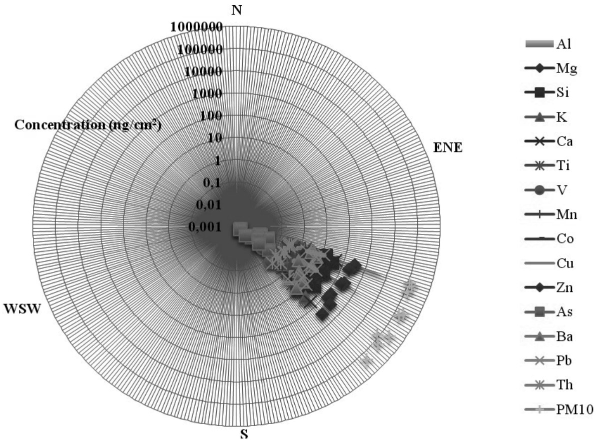

FIGURE 12. Dispersion of atmospheric elements according to wind direction at Country Heights Kajang

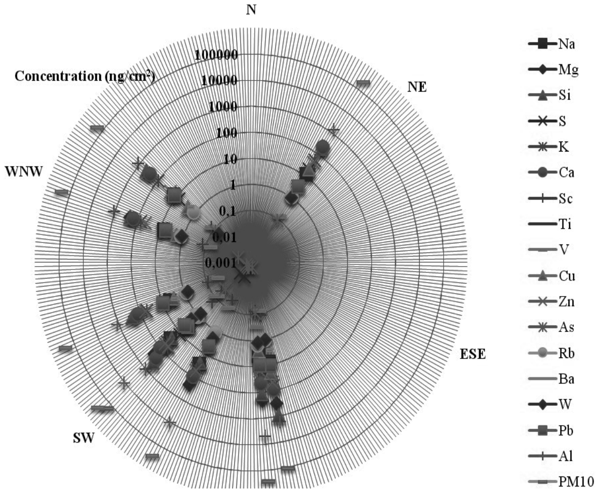

FIGURE 13. Dispersion of atmospheric elements according to wind direction at Jalan Hang Tuah Kuala Lumpur

SOURCE APPORTIONMENT OF ACCUMULATED AIRBORNE POLLUTANTS

In order to identify the possible sources of detected elements on the leaves surfaces of both sites, Principle Component Analysis was conducted using Varimax with Kaiser Normalization of rotated component matrix. Based on Table 3 and 4, there were 10 components detected which represent the possible sources of each element that distributed on the leaves surfaces of *A. siamensis* and *F. microcarpa*. The elements were assigned according to the percentage of variances as well as the identified sources. At Country Heights Kajang, K and Ca computed the highest percentage of variance (7.898%) while Si and Sc computed the lowest percentage of variance (5.758%). However, Sc, Ni, Cr, Ti and S computed the highest percentage of variance (17.592%) while PM computed the least (4.173%) at Jalan Hang Tuah Kuala Lumpur. It could be seen that there were differences in the assigning of respective elements in each component of both study sites. This could be due to different types of location with different kinds of activities that contribute to various types of airborne pollutants. Country Heights Kajang for instance, the highest percentage of variance is the sources originated from construction or cement plant (Figure 14). In contrast, sediments or re-suspended road dusts computed the higher percentage of variances at Jalan Hang Tuah Kuala Lumpur as those summarized in Figure 15.

The results indicated that Jalan Hang Tuah Kuala Lumpur had different kind of activities compared to Country Heights Kajang. This is because Jalan Hang Tuah is situated in the centre of Metropolitan urban city of Kuala Lumpur whereas Country Heights Kajang is only a residential area in which the activities are limited into household courses, light construction and limited number of vehicles. Therefore, the airborne pollutants that been dispersed in Jalan Hang Tuah Kuala Lumpur were different compared to Country Heights Kajang. The remarkably higher percentage of variances in the urban site of Kuala Lumpur was greatly influenced by the multiple anthropogenic and natural sources which these sources were less available in the residential area of Country Heights Kajang. 17.59% of sediments or re-suspended road dusts found in Jalan Hang Tuah Kuala Lumpur indicate that the elements were dispersed by the vehicles' tyres upon impaction which were then bounced off onto the leaves surfaces of *F. microcarpa*. The abundances of these elements were due to the frequent traffic congestion in the urban city of Kuala Lumpur.

However, there were construction works being done at Country Heights Kajang during the sampling days, in relation to the highest percentage of variances for this type of source (7.90%). The constructions involved were renovation of houses and construction of a new house nearby the sampling site. Lorries and tractors were frequently passing through the site dispersing along the elements together. As a result, the dispersed elements were deposited onto the leaves surfaces significantly.

TABLE 3. Principle Component Analysis using Rotated Component Matrix[a] for Country Heights, Kajang (*A. siamensis*)

	Component									
	1	2	3	4	5	6	7	8	9	10
Potassium	.900									
Calcium	.802									
Sodium		.837								
Aluminium		.815								
Magnesium		.410						.370		
Barium			.875							
Cerium			.726							
Antimony				.738						
Titanium			-.311	.687						
Lead					.725					
Thorium					.632					
Particulate Matter					-.611		.420			
Arsenic						.734				
Tungsten						.674	-.347			
Manganese			.330			.449		.376	-.313	
Zinc							.711			
Copper				.399			.513			
Samarium								.717		
Cobalt	.309							.585		
Rububium									.756	
Vanadium							.394		.591	
Silicon										.762
Scandium									-.487	.616
% of Variance	7.898	7.892	7.563	6.956	6.541	6.533	6.509	6.119	6.037	5.758
Major elements	K, Ca	Na, Al	Ba, Ce	Ti, Sb	Pb, Th, PM	As, W	Zn, Cu	Sm, Co	Rb, V	Si, Sc
Minor elements	Co	Mg	Ti, Mn	Cu	-	Mn	PM, W, V	Mn, Mg	Mn, Sc	-
Identified sources	Construction works / cement plant	Sea salt / Soil-derived	Rear earth element	Soil fraction + Construction	Vehicle engine / wear / Smelter	Smelter + Coal combustion	Combustion (mixture of oil and coal) + Industry	Industrial plant + Crustal elements	Oil of industrial + fossil fuels combustion	Soil fraction + Construction

Note: Bold values show clustered elements from the same sources. Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; [a] Rotation converged in 32 iterations.

TABLE 4. Principle Component Analysis using Rotated Component Matrix^a for Kuala Lumpur (*F. microcarpa*)

	Component									
	1	2	3	4	5	6	7	8	9	10
Scandium	.982									
Nickel	.980									
Chromium	.980									
Titanium	.895	.344								
Sulphur	.813	.416								
Potassium		.900								
Calcium		.803								
Silicon		.742								
Antimony		.666								
Iron		.620				.343				
Copper			.920							
Zinc			.841							
Barium				.845						
Cerium	.464			.702						
Sodium					.795					
Aluminium					.696					
Magnesium					.483	.433				
Lead						.740				
Arsenic						-.624				
Vanadium							-.767			
Thorium							-.614			
Tungsten								-.650		
Rubidium								.624		
Samarium								.379		
Manganese									-.771	
Cobalt				-.320				.348	.401	.322
Particulate Matter										-.848
% of Variance	17.592	13.398	7.019	6.106	5.756	5.580	5.224	5.162	4.370	4.173
Major elements	Sc, Ni, Cr, Ti, S	K, Ca, Si, Sb, Fe	Cu, Zn	Ba, Ce	Na, Al	Pb, As	V, Th	W, Rb	Mg	PM
Minor elements	Ce	Ti, S	-	Co	Mg	Fe, Mg	-	Co	Co	Co
Identified sources	Sediments / Re-suspended road dust	Construction works / cement plant	Combustion (mixture of oil & coal) / Industry	Rare earth element	Sea salt / soil-derived	Smelter + petrol combustion	Residual oil combustion	Industrial	Firework combustion	Road / vehicle wear / fuel combustion

Note: Bold values show clustered elements from the same sources. Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; ^{a} Rotation converged in 29 iterations.

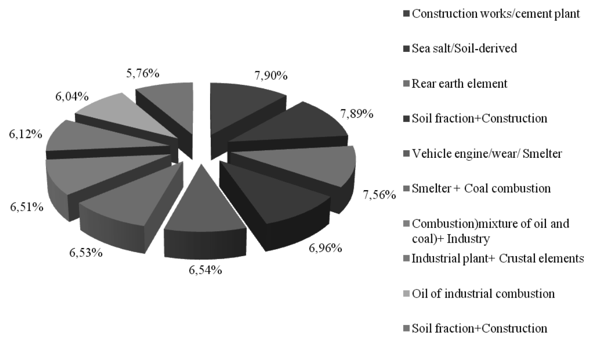

FIGURE 14. Summary of identified sources of airborne pollutants at Country Heights Kajang according to the percentage of variance

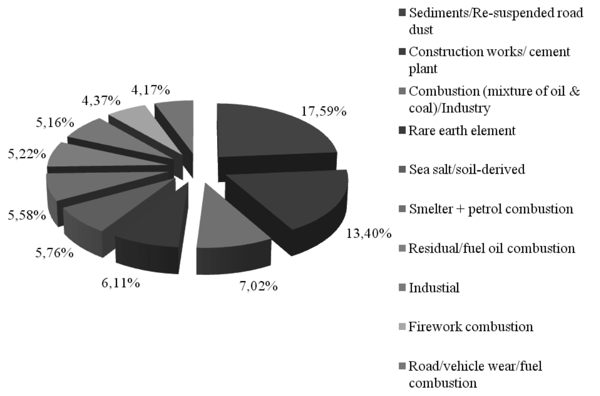

FIGURE 15. Summary of identified sources of airborne pollutants at Jalan Hang Tuah Kuala Lumpur according to the percentage of variance

Enrichment Factor (EF) was also been applied to identify the possible sources of airborne pollutants. Olubunmi and Olorunsula (2010) stated that EF can be used to differentiate between the pollutants originating from anthropogenic activities and those from natural sources, and to access the degree of anthropogenic influence. Based on Figures 16 and 17, there were 17 elements that were significant to extremely enriched at Country Heights Kajang, whereas 12 elements were significant to extremely enriched at Jalan Hang Tuah Kuala Lumpur. These enriched elements were influenced by the human activities that frequently occurring at the urban site of Kuala Lumpur as well as Country Heights Kajang during the sampling periods. These elements were highly correlated with the results obtained through the Principle Component Analysis where the identified sources of these elements mostly from the anthropogenic sources. The broad range of relationship between elements was due to the availability of various sources originated from human activities in such of the urban site. Among these elements, the EF of Sb, Pb, W, Zn and Cu where higher than 100 for both study sites which showed that Sb, Pb, W, Zn and Cu pollution were more serious.

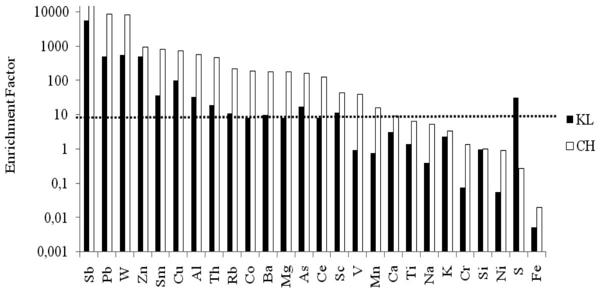

FIGURE 16. Aerosols of PM enrichment factors (EF) relative to silica (Si) as reference element for crustal origin

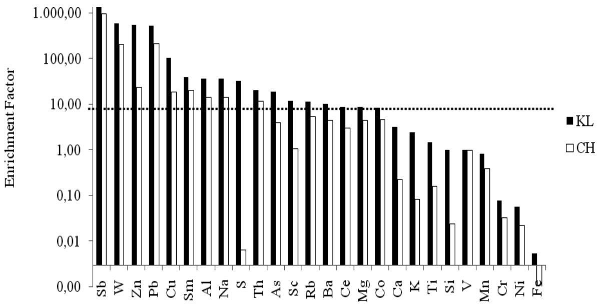

FIGURE 17. Aerosols of PM enrichment factors (EF) relative to Vanadium (V) as reference element for crustal origin

CONCLUSION

This study was conducted to estimate the airborne particulates deposited on the leaves of two different plants species at Kuala Lumpur and Kajang as well as to determine the possible sources of deposited particulates matter. The results showed that different species of plants have different concentration of deposited airborne particulates. There were 162573.141±14179.174 ng/cm^2 elements and particulate matters that were collected on the leaves of *A. siamensis* at Country Heights Kajang whereas 239457.042±23554.892 ng/cm^2 of airborne pollutants deposited on the leaves of *F. microcarpa* at Jalan Hang Tuah Kuala Lumpur throughout the sampling periods. This shows that these plants species are recommended to be planted in urban areas as they are able to capture airborne pollutants effectively as they have leaves with trichomes and waxy layer, respectively. The finding shows 27 elements including particulate matter which were identified in this study. Different study sites have different types of elements. The differences occurred was likely due to the different background of study sites where Jalan Hang Tuah Kuala Lumpur was known to be more urbanized than the residential area of Country Heights Kajang. Through the Enrichment Factor (EF), there were 17 elements that were significant to extremely enriched at Country Heights Kajang namely Sb, Pb, W, Zn, Sm, Cu, Al, Th, Rb, Co, Ba, Mg, As, Ce, Sc, V and Mn, whereas 12 elements were significant to extremely enriched at Jalan Hang Tuah Kuala Lumpur; Sb, Pb, W, Zn, Sm, Cu, Al, Th, Rb, As, Sc and S. EF shows that these elements originated from the anthropogenic sources as the values were greater than 10. It was found that the elements present in Country Heights Kajang was blown from South East (SE) and East South East (ESE) whereas the elements were blown from North East (NE), North North East (NNE), South (S), South South West (SSW), South West (SW), West South West (WSW), West North West (WNW) and North West (NW) into Jalan Hang Tuah Kuala Lumpur. There were various directions of pollutant dispersion in Kuala Lumpur compared to Country Heights Kajang due to various anthropogenic activities that were available surrounding the study site besides of the effect from wind directions during the sampling period. Hence, plants that have leaves with trichomes, waxy layer, broader surface and tolerant to the harsh environment are highly recommended to be planted in a city which could reduce the airborne pollutants significantly.Therefore, it is important for the respective authorities as well as the public to implement proper strategies in achieving a goal of being a sustainable green country for the next coming years.

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