DETERMINATION OF TOTAL POLYCYCLIC AROMATIC HYDROCARBON (PAHs) IN ROAD DUST ALONG KUANTAN-GAMBANG ROAD

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ABSTRACT

Polycyclic Aromatic Hydrocarbons (PAHs) is a type of potential environments pollutants which consists of fused aromatic rings. PAHs do not contain heteroatoms or carry any substituents. Anthracene is one of the simplest examples of PAHs. PAHs are formed by incomplete combustion of carbon materials such as wood, coal, and diesel. PAHs generated through combustion will emit to the ambient air as gases and particles. When the atmospheric PAHs escaped the photo-degradation in the air, they will be accumulated to the land surface. In this study, road dust sample was collected along the Kuantan-Gambang road and the Polycyclic Aromatic Hydrocarbon (PAHs) content then determined. Several main road lines in Kuantan-Gambang road were selected as sampling sites covering residential area, mining area, behind the FIST lab in UMP campus and etc. The samples were analyzed for the presence of total Polycyclic Aromatic Hydrocarbon (PAHs). Ultrasonic Agitation was used for the sample extraction. Next, the extracts were analyzed by UV-fluorescence spectrophotometer (Cary 50 Conc UV-Fluorescence Spectrophotometer Model) in order to determine the total PAHs at 254 nm excitation wavelength. The fluorescence intensities were measured at 360 nm, using crude oil solution as quantitative standard.

ABSTRAK

Polisiklik aromatic hidrokarbon (PAHs) adalah sejenis penemaran persekitaran yang terdiri daripada paduan lingkungan cincin. PAHs tidak mempunyai sebarang heteroatoms atau sebarang gentian. Anthrance adalah salah satu contoh PAHs yang ringkas. PAHs terjadi akibat daripada pembakaran karbon yang tidak sempurna, di mana terdapatnya bahan bakar seperti arang, kayu dan juga diesel. PAHs yang terhasil melalui pembakaran akan terbebas di udara dalam bentuk gas dan zarah. Ketika PAHs membolosi foto-degradasi di udara, mereka akan di kumpulkan di atas permukaan bumi. Sampel debu jalanan telah di kutip kali ini di sepanjang jalan Gambang-Kuantan dan kemudian kandungan PAHs tentukan. Beberapa jalan utama sepanjang jalan Gambang-Kuantan telah di pilih sebagai kawasan sampel termasuk bebrapa kawasan perumahan, kawasan lombong, belakang makmal FIST di dalam kampus UMP serta beberapa kawasan lain lagi. Sampel kemudian di analisis untuk mengetahui kewujudan jumlah polisiklik aromatic hidrokarbon seperti yang telah disenaraikan oleh USEPA. Ultrasonic agitator telah digunakan untuk mengekstrak sample. Seterusnya, sample yang telah di ekstrak telah di analisis olehspektrometri UV-Fluorescence (Model Cary 50 Conc UV-Fluorescence Spectrophotometer) untuk menentukan jumlah PAHs dengan 254 nm panjang gelombang pengujaan. Keamatan pendarfluor di ukur pada 360 nm menggunakan minyak mentah sebagai standard kuantitatif.

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LIST OF SYMBOLS

μ	Micro
≤	Less than or equal to
≥	Greater than or equal to

LIST OF ABBREVIATIONS

ANTH	Anthracene
BaA	Benz[a]anthracene
BaP	Benzo[a]pyrene
BbF	Benzo[b]fluoranthene
BeP	Benzo[e]pyrene
BgP	Benzo[g,h,i]perylene
BkF	Benzo[k]fluoranthene
CHR	Chrysene
COR	Coronene
CONC	Concentrations
FLT	Fluoranthene
PAHs	Polycyclic Aromatic Hydrocarbon
PHEN	Phenanthrene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Street dust on the impervious surface along the road can be the important sources for the determination of PAHs in road dust pollution. According to the study by Kavouras et al., (2001), as a persistent organic pollutants (POPs), Polycyclic Aromatic Hydrocarbon (PAHs) are highly degraded, hydrophobic, lipophilic and carcinogen. PAHs are formed from the combustion of carbonaceous materials and it are ubiquitous environmental pollutants. The United States Environmental Protection Agency (USEPA) has placed 16 of these PAHs in the priority list due to this consideration. Immunotoxicity, genotoxicity, carcinogenicity, and reproductive toxicity are the examples of the adverse effects due to the induce number of PAHs (John and Line, 2002). The road from Gambang to Kuantan is about 30 km. Construction of highways and improvement of the road network has been carried out intensively to improve the infrastructure of this main road which connects to Johor, Kuala Lumpur and Terengganu. Automobile exhaust is an important source of PAHs in the atmosphere, which will finally be deposited on soil or as street dust. Therefore, road dust is chemically similar to the primary portion of the atmospheric aerosol. Analysis of road dust can reflect the pollution level in the atmosphere. Therefore, these studies focus on the determination of PAHs in road dust along the Gambang-Kuantan road.

1.1 PROBLEM STATEMENT

King et al., (2002) stated that PAHs was the number ninth ranked as the most threatening compound to human health in the year of 2001. Based on their genotoxic potentials, the higher the molecular weight of PAHs, the more dangerous it would be. This study responds to the call to determine the Polycyclic Aromatic Hydrocarbon (PAHs) in road dust along the Kuantan-Gambang road. This is due to the Kuantan-Gambang road is the main road which connects 3 states (Kuala Lumpur,Johor and Terengganu), and also interchange to Kuantan Airport and East Coast Expressway at Gambang exit. Heavy traffic flow at this road might produce significant amount of PAHs to the environment, giving rise to public concern about the possible health effect due to inhalation of street dust.

1.2 RESEARCH QUESTIONS

This study embraces some research questions, which are;

i. What is Polycyclic Aromatic Hydrocarbon (PAHs)?

ii. What are the possible sources of PAHs in road dust?

iii. How human activities affect the distribution of PAHs in road dust?

1.3 RESEARCH OBJECTIVES

In this study, we focused on two main objectives which are;

i. To determine the concentration of Polycyclic Aromatic Hydrocarbon (PAHs) contains in road dust.

ii. To investigate the distribution of PAHs in different area along the Kuantan-Gambang road.

1.4 RATIONALE AND SIGNIFICANCE

The rationale of this proposed research project is to determine and compare the concentration of PAHs in road dust along Kuantan-Gambang road. The results of this research would provide a background data about the distribution of PAHs in the studied area.

CHAPTER 2

LITERATURE REVIEW

2.1 POLYCYCLIC AROMATIC HYDROCARBON (PAHs)

Polycyclic Aromatic Hydrocarbon (PAHs) are a group of organic compounds with two or more fused aromatic rings. The incomplete combustion of organic matter contribute to the originate of PAHs. PAHs that are generated through the incomplete combustion are emitted to ambient air in particulates and gases. By escaping photo degradation in the air, atmospheric PAHs are accumulated to land surface through dry and wet deposition. The PAHs then either become incorporated into soil or become street dust. Crude palm oil and petroleum products can be another important source of PAHs. Kerosene, gasoline, diesel, fuel and asphalt are the examples of the petroleum products. High exposure to PAHs can contribute to health effect problem. Armstrong et al., (2004), Chen and Liao, (2006), Boffetta et al., (2004) and Kameda et al., (2005) stated that human cancer causes of skin, lungs, and bladder have always been associated with the PAHs exposures.

2.1.1 Physical Characteristics of PAHs

Physical and chemical characteristics of PAHs vary with molecular weight. For instance, PAH resistance to oxidation, reduction, and vaporization increases with increasing molecular weight, whereas the aqueous solubility of these compounds decreases. As a result, PAHs differ in their behaviour, distribution in the environment, and their effects on biological systems. PAHs can be divided into two group which is based on its physical, chemical and biological characteristics. The lower molecular weight of PAHs, for examples 2 to 3 ring groups has significant acute toxicity to aquatic organisms. Naphthalene is one of the PAHs with the low molecular weight. The high molecular weight of PAHs,for examples chrysenes, do not. However, several members of the high molecular weight PAHs have been known to be carcinogenic. The physical-chemical characteristics of PAHs are shown in Table 2.1.

Table 2.1: Physical-chemical characteristics of some PAHs

Physical-chemical characteristics of some PAHs * (From Neff, 1979; CCREM, 1987; NRCC, 1983; USPHS, 1990)						
PAH	**Mol.Wt. (g)**	**Solubility at 25 °C (µg/L)**	**Vap. Pressure at 25 °C (mm Hg)**	**Log Kow (Log Koc)**	**Carcino-genicity**	**Benzen (and total) rings**
Naphthalene	128.2	12500 to 34000	1.8x 10^{-2}	3.37	NC	2
Acenaphthylene	152.2	3420	10^{-3} - 10^{-4}	4.07 (3.40)	NC	2
Acenaphthene	154.2			3.98 (3.66)	NC	2
Fluorene	166.2	800		4.18 (3.86)	NC	2 (3)
Anthracene	178.2	59	2.4x 10^{-4}	4.5 (4.15)	NC	3
Phenanthrene	178.2	435	6.8x 10^{-4}	4.46 (4.15)	NC	3
Acridine	179.2			(4.48)	NC	3
2-Methylanthracene	192.3	21.3		4.77	NC	3
9-Methylphenanthrene	192.3	261		4.77	NC	3
1-Methylphenanthrene	192.3	269		4.77	NC	3
Fluoranthene	202.3	260		4.90 (4.58)	NC	3 (4)
9,10-Dimethylanthracene	206.3	56		5.13	NC	3
Benzo[a]fluorene	216.3	45		5.34	NC	3 (4)
Benzo[b]fluorene	216.3	29.6		5.34	NC	3 (4)
Pyrene	202.1	133	6.9x 10^{-7}	4.88 (4.58)	NC	4
Benz[a]anthracene	228.3	11.0	1.1x 10^{-7}	5.63 (5.30)	C	4
Naphthacene	228.3	1.0		5.65	NC	4
Chrysene	228.3	1.9		5.63 (5.30)	WC	4
Triphenylene	228.3	43		5.63		4
Benzo[b]fluoranthene	252.3	2.4		6.04 (5.74)	C	4 (5)
Benzo[j]fluoranthene	252.3	2.4		6.21	C	4 (5)
Cholanthrene	254.3	2.0		6.28	C	4 (5)

Table 2.1: Continued

Physical-chemical characteristics of some PAHs * (From Neff, 1979; CCREM, 1987; NRCC, 1983; USPHS, 1990)						
PAH	**Mol.Wt. (g)**	**Solubility at 25 °C (μg/L)**	**Vap. Pressure at 25 °C (mm Hg)**	**Log Kow (Log Koc)**	**Carcino-genicity**	**Benzene (and total) rings**
Dibenzo[a,h]fluorene	266.3	0.8		6.57	WC	4 (5)
Dibenzo[a,g]fluorene	266.3	0.8		6.57	C	4 (5)
Dibenzo[a,c]fluorene	266.3	0.8		6.57	WC	4 (5)
3-Methylcholanthrene	267.3	0.7		6.64	SC	4 (5)
Benzo[ghi]fluoranthene	214.2	0.5		6.78	NC	4 (5)
Benzo[a]pyrene	252.3	3.8	$5.5\text{x } 10^{-9}$	6.06 (5.74)	SC	5
Benzo[e]pyrene	252.3	2.4	$5.5\text{x } 10^{-9}$	6.21	NC	5
Perylene	252.3	2.4		6.21	NC	5
Indeno(1,2,3-cd)pyrene	276.3	-		6.58 (6.20)	C	5(6)
Dibenz[a,h]anthracene	278.3	0.4		6.86 (6.52)	C	5
Benzo[ghi]perylene	276.4	0.3	$1.0\text{x } 10^{-10}$	6.78 (6.20)	NC	6
Coronene	300.3	0.14	$1.5\text{x } 10^{-11}$	7.36	NC	7

* NC= non-carcinogenic; WC=weakly carcinogenic; C=carcinogenic; SC=strongly carcinogenic; Kow=Octanol/water partition coefficient; Koc= partitioning coefficient for organic carbon.

2.1.2 Sources of PAHs

PAHs either in urban or industrial atmosphere possess a range of chemical, physical and toxicological characteristics. They are almost entirely anthropogenic in origin and are major by products of the incomplete combustion of all types of organic matter (Park et al., 2002 and Wingfors et al., 2001). Moreover, PAHs are ubiquitous environmental pollutants which are formed in the combustion of carbonaceous materials such as diesel, gasoline and other fuel at very high temperature (Liu et al., 2001 and Kavouras et al., 2001). Motor vehicles can be one of the most serious sources of PAHs (Shimmo et al., 2002) The sources of PAHs can be derived from 2 sources which are natural sources and anthropogenic sources.

2.1.2.a. Natural Sources of PAHs

Volcanic activities and forest fires can be categorized under the natural sources of pyrogenic PAH.

2.1.2.b. Anthropogenic Sources of PAHs

Anthropogenic sources can be divided into two category which are:

- Combustion of materials for energy supply
- Combustion for waste minimization

Coal, oil, gas and the stationary sources can be the examples of combustion of materials for energy supply. Industry (coke and carbon production, petroleum processing), residential heating (gas and oil burners, furnaces) and power and heat generation (coal, oil, wood) are the examples of stationary sources. Studies also show that emission from vehicle exhaust such as diesel, leaded and leaded gasoline are the largest contributors of PAHs in the urban area (Rogge et al., 1993a; Khalili et al., 1995; Miguel et al., 1998; Marchandet al.,2004; Ravindra et al., 2006a and Ravindra et al., 2006b; Marr et al., 2006).Moreover, Paturel et al. (1996) found that the start of conditions of vehicles, either hot or cold engine have a little influence on mass repartition of PAHs in gaseous or in particulate phase.

Combustion for waste minimization covers incineration of municipal and industrial waste. Agricultural burning, crematoria, cigarette smoking as well as volatilization from soils, vegetation and other surfaces are the types of other miscellaneous sources.

2.1.3 Health Effect of PAHs

PAHs are easily found throughout the environment either in the air, water and soil. Xu et al., (2006) reported that consumptions of fossil fuels has emits a large quantity of PAHs into the environment in China. One of the major sources is from motor vehicles emission in urban areas. According to Bispo et al., (1999) and Geffard et al., (2003) PAHs contamination of urban atmosphere has brought much concern due to their acute to chronic toxic effects on the living organisms. Li et al., (2005) reported that 20%of the total exposure in Tianjin was through inhalation. Tao et al., (2006) had done investigation including urban districts and rural countries in Tianjin. Due to the result, it shows that inhalation exposure was more severe in the urban districts where the PAHs levels in the ambient air commonly exceeds values for rural areas.

The health effects that can be caused by exposure to PAHs depend on:

- How much PAHs entered the body?
- How long did the body have been exposed?
- How the body responds to PAHs?

All those effects may be either in short term or long term.

2.2 ROAD DUST

Road dust is a complex mixture of particles from a number of natural and anthropogenic sources which have been found to contain carcinogenic components and heavy metals from exhaust and non-exhaust processes, along with mold spores and pollen fragments (Eric et al., .2011). According to Kupianen.,(2007) by passing vehicle-induced turbulence and shearing stress of the tires or wind, road dust can subsequently become resuspended. Figure 2.1 shows the cycle of the road dust deposition.

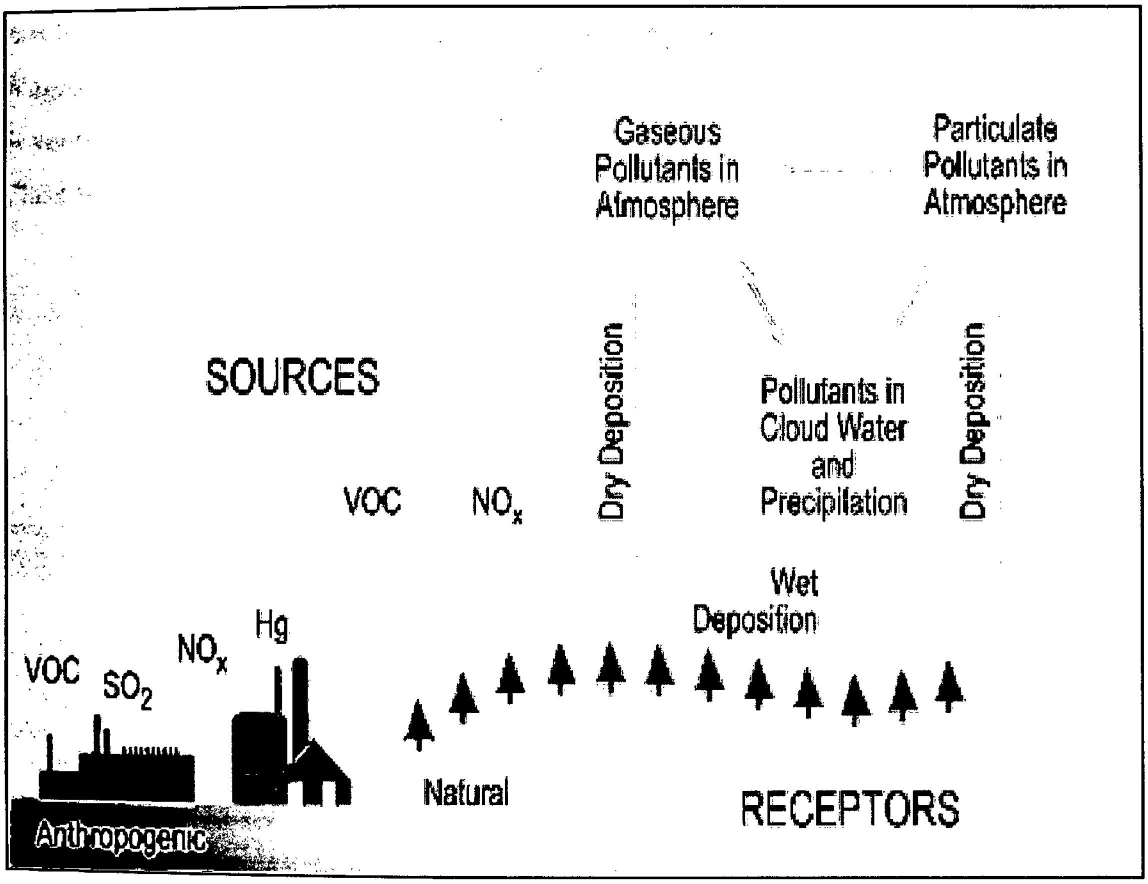

Figure 2.1 : Cycle of road dust deposition

2.3 PREVIOUS STUDY ABOUT PAHs

M.A. Hassanien and N.M. Abdel-Latif (2008) done a research on the total concentration of polycyclic aromatic hydrocarbons in road dust of different sites over Greater Cairo. They found that PAHs can be classified according to their number of aromatic ring as follows: 2-ring including NAP; 3-ring includingACE,FLU,PHEand ANC; 4-ring including FLA, PYR, BaA and CHR; 5-ring including BbF, BkF and BaP. The most abundant PAHs were 3-and 4-ring compounds with percentages of 61 and 35, respectively. This report was consistent with Trapido (1999) who reported the dominance of 3–4 ring PAHs in Estonian soil. Li et al., (2006) stated that total 12 PAHs was seven-fold higher than the natural and background level of PAHs at remote or rural sites (0.1 mg/kg). According to Tremolada et al., (1996) and Wagrowski and Hites, (1997) PAHs in urban soilswas 2–10 higher than rural ones. Seventeen sampling sites were selected to represent different sectors in greater Cairo. Classification of sites, according to the main activity, is shown in Table 2.2.

Table 2.2: Locations and character sites over Greater Cairo

Number	Site	Character activity
1	Naser city	Residential
2	Salah Salem street	Traffic
3	South 15th May city	Traffic
4	Shobra El Kheima	Mixed area
5	Ramsis square	Traffic
6	Obera square	Traffic
7	Dar El Salam	Residential
8	El Warak	Mixed area
9	Dokki square	Traffic
10	Cairo University	Traffic
11	Giza square	Residential
12	Saft El Laban	Residential
13	Hario square El Maadi	Residential
14	El Maadi	Residential
15	El MaadiAutostrad	Traffic
16	El Basateen	Residential
17	Maruotya	Residential

Seventeen sampling sites were selected to represent different sectors in greater Cairo during 2005. Figure 2.2 below shows the map of the Greater Cairo with location of road dust sampling sites.

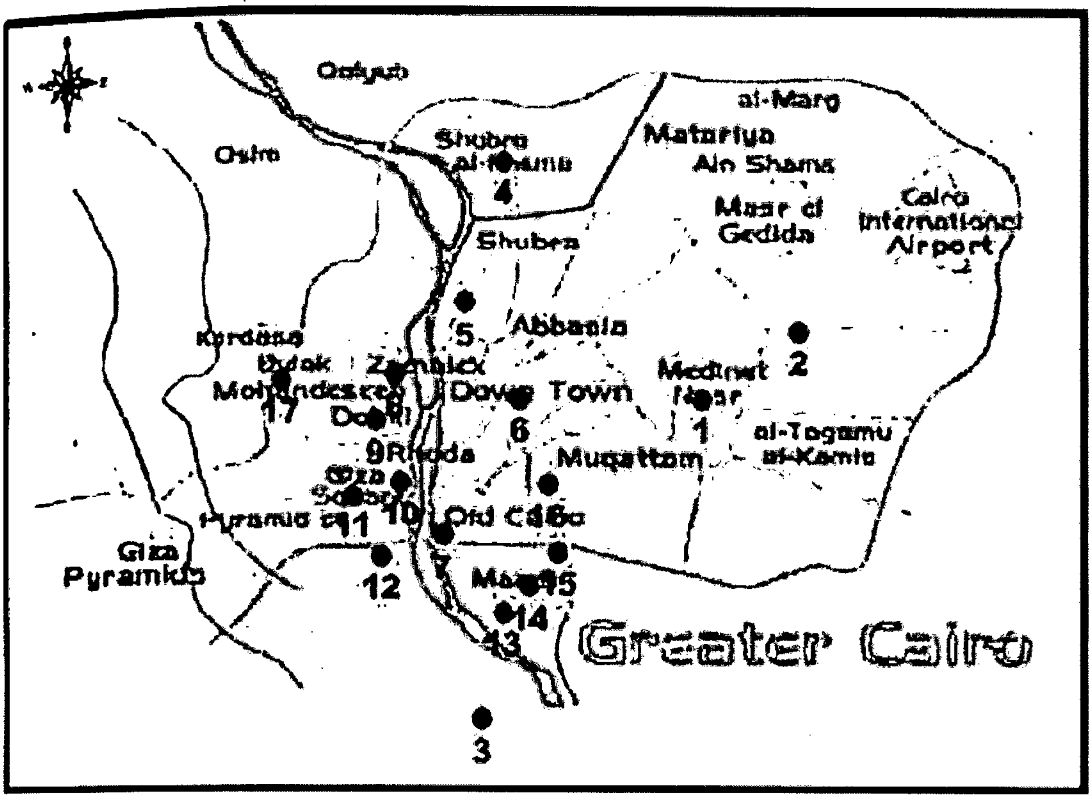

Figure 2.2: Map of the Greater Cairo with location of road dust sampling sites

From the Figure 2.2 above, Sites 4 and 8 represent the heavily industrialized area in north Cairo, while sites 3, 13, 14,15 and 16 are located close to the major industrial area south Cairo. Despite of traffic activities in all sites, downtown sites (5, 6, 9 and 10), industrial and mixed sites (4 and 15) and residential sites (11, 13 and 16) are the most heavily traffic in this study. All residential sampling sites are high dense populated and characterized by the presence of several urban activities, including scattered vehicles service centers.

Table 2.3: Total concentration of polycyclic aromatic hydrocarbons (mg/kg) in road dust of different sites over Greater Cairo.

Site	PAHs species											
	NAP[a]	ACE	FLU	PHE	ANC	FLA	PYR	BaA[a]	CHR[a]	BbF[a]	BkF[a]	BaP[a]
1	0.0093	0.0082[b]	0.0006	0.0060	0.0086	0.0029	0.0091	0.0004	0.0065	0.0017	0.0003[c]	0.0003
2	0.0100	0.0082	0.0006[c]	0.0060	0.0150	0.0004[c]	0.0010	0.0004[c]	0.0008	0.0017	0.0004	0.0003
3	0.0075	0.0009	0.0006	0.0074	0.0150[b]	0.0004	0.0036	0.0035	0.0027	0.0017	0.0031	0.0009
4	0.0618[b]	0.0015	0.0413[b]	1.0284[b]	0.0150	0.3906[b]	1.0312[b]	0.0035	0.0027	0.0195	0.0050	0.0110
5	0.0178	0.0015	0.0413	0.8540	0.0016[c]	0.0060	0.0070	0.0005	0.0008	0.0195[b]	0.0070	0.0110[b]
6	0.0415	0.0005[c]	0.0413	0.8540	0.0086	0.1603	0.4178	0.0035	0.0023	0.0032	0.0003	0.0011
7	0.0428	0.0005	0.0149	0.1561	0.0016	0.0131	0.0682	0.0035	0.0008	0.0032	0.0003	0.0009
8	0.0087	0.0005	0.0169	0.0016[c]	0.0016	0.0178	0.0027	0.0036	0.0023	0.0007	0.0040	0.0009
9	0.0187	0.0007	0.0169	0.0074	0.0016	0.1565	0.0027	0.0036	0.0023	0.0006	0.0070	0.0009
10	0.0210	0.0008	0.0012	0.0074	0.0016	0.1565	0.0006[c]	0.0036	0.0023	0.0008	0.0070	0.0031
11	0.0040[c]	0.0070	0.0160	0.7380	0.0080	0.0178	0.4100	0.0036	0.0639[b]	0.0008	0.0070	0.0011
12	0.0384	0.0053	0.0169	0.7129	0.0080	0.1565	0.3927	0.0036	0.0639	0.0005	0.0040	0.0021
13	0.0052	0.0020	0.0058	0.8020	0.0086	0.0180	0.4060	0.0007	0.0006[c]	0.0032	0.0004	0.0011
14	0.0197	0.0020	0.0040	0.0705	0.0080	0.0126	0.0438	0.0065	0.0008	0.0006	0.0070	0.0021
15	0.0169	0.0020	0.0044	0.0072	0.0086	0.0140	0.0050	0.0065[b]	0.0009	0.0005	0.0080[b]	0.0031
16	0.0374	0.0020	0.0044	0.8020	0.0040	0.0180	0.0061	0.0007	0.0008	0.0004[c]	0.0040	0.0011
17	0.0040	0.0020	0.0044	0.8020	0.0020	0.0180	0.0072	0.0007	0.0010	0.0005	0.0030	0.0001[c]
Average	0.0215	0.0027	0.0136	0.4037	0.0069	0.0682	0.1656	0.0028	0.0091	0.0035	0.0040	0.0024

NAP, naphthalene; ACE, acenaphthene; FLU, fluorene; PHE, phenanthrene; ANC, anthracene; FLA, fluoranthene; PYR, pyrene; BaA, benzo(a)anthracene; CHR, chrysene; BbF, benzo(b)fluoranthene; BkF, benzo(k)fluoranthene; BaP, benzo(a)pyrene.

[a] Carcinogenic compounds.

[b] Maximum concentration carcinogenic contents.

[c] Minimum concentration carcinogenic contents.

From Table 2.3, the highest total content of detected PAHs in road dust were recorded at sites 4, 6, 11 and 12 with values 2.61, 1.53, 1.40 and 1.28 mg/kg respectively as illustrated in Table 2.2. Meanwhile, the lowest values were recorded at sites 1,2 and 3 with 1.154, 0.045 and 0.047 mg/kg. Compared to the other sites of higher PAHs level, the low levels sites could be attributed to low densities/congestion and the absence of the big industrial activities.

N.Y.M.J. Omar et al. (2006) done a research on concentrations (arithmetic mean±S.D.) of PAHs and their BaPeq concentrations using Nisbet and LaGoy's (1992) TEFs. Table 2.5 shows the main particulate PAHs according to their elution orders phenanthrene (PHEN), anthracene (ANTH), fluoranthene (FLT), pyrenc(PYR), benz[a]anthracene (BaA), chrysene (CHR), benzo[b]fluoranthene

(BbF), benzo[k]fluoranthene(BkF), benzo[e]pyrene (BeP), benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (IP), benzo[g,h,i]perylene (BgP), and coronene (COR).

Table 2.4: Concentration (arithmetic mean±S.D.) of PAHs and their BaPeq concentrations using Nisbet and LaGoy's (1992)TEFs.

PAHs	TEFs	Street KL[a] (n=24)		Ambient UM[b] (n=19)		Haze[c] (n=2)	
		Conc. (ng/m^3)	BaP_{eq} (pg/m^3)	Conc. (ng/m^3)	BaP_{eq} (pg/m^3)	Conc. (ng/m^3)	BaP_{eq} (pg/m^3)
PHEN	0.001	0.17±0.11	17±0.11	n.d.	0	n.d.	0
ANTH	0.010	0.09±0.05	0.87±0.45	n.d.	0	n.d.	0
FLT	0.001	0.12±0.08	0.12±0.08	n.d.	0	n.d.	0
PYR	0.001	0.33±0.21	0.33±0.21	0.04±0.09	0.04±0.09	n.d.	0
BaA	0.100	0.16±0.12	16.33±11.75	n.d.	0	1.23±0.52	123.72±51.74
CHR	0.010	0.19±0.13	1.90±1.30	0.07±0.15	0.70±1.50	1.79±0.32	17.89±3.17
BbF	0.100	0.35±0.27	35.30±27.28	0.25±0.28	25.26±27.81	8.66±0.57	865.83±56.92
BkF	0.100	0.24±0.18	24.11±18.19	0.38±0.44	37.74±43.64	6.13±0.63	613.12±62.81
BeP	–	0.57±0.40	–	0.37±0.45	–	2.20±0.08	–
BaP	1.00	0.47±0.36	467.93±356.35	0.16±0.18	156.17±184.09	0.05±0.03	53.50±25.46
IP	0.10	0.69±0.57	69.35±57.17	0.47±0.56	46.58±55.70	7.78±0.75	777.72±75.17
BgP	0.01	1.35±0.95	13.53±9.46	0.76±0.87	7.57±8.66	14.41±1.39	144.06±13.94
COR	–	1.11±0.94	–	0.61±0.69	–	5.64±0.29	–
Total		5.85±4.05	629.94±470.9	3.10±2.92	274.05±313.64	47.89±0.09	2595.82±147.4
Kolmogorov-Smirnov "goodness of fit" test[d]		P=0.775 (normal)	P=0.696 (normal)	P=0.307 (normal)	P=0.334 (normal)		
95% CI[e]		4.14–7.56	431.06–828.82	1.69–4.51	122.88–425.22		
Student's t-test (PAHs)[f]	t=−2.491, P=0.0169						
Student's t-test (BaP_{eq})[f]	t=−2.831, P=0.0072						
Total (geometric mean)		4.30	434.20	2.07	198.64		
95% CI[g]		2.94–6.30	284.78–662.00	1.32–3.24	112.33–351.26		
BeP/(BeP+BaP)		0.55		0.71		0.98	
%BaP/total BaP_{eq}			74.28		57.00		2.06

n.d.: not detected
–: no TEF has been suggested.
[a] Street level atmospheric particles (Omar et al., 2002).
[b] Ambient level atmospheric particles (present study).
[c] Haze smoke atmospheric particles (Abas et al., 2004).
[d] Test for normal distribution of total PAHs and total BaP_{eq}.
[e] Confidence interval for the arithmetic mean at the 95% confidence level.
[f] Student's t-test for total PAHs and total BaP_{eq} applied to street KL and ambient UM at the P=0.05 level assuming normal distribution.
[g] Confidence interval for the geometric mean at the 95% confidence level.

According to Polkowska et al., (2000) the fluctuations in the observed PAHs concentrations (Table 2.4) may due to the seasonal variations such as the dry season's natural fires that increase the input of PAHs into the atmosphere. Moreover, wet deposition is an effective removing LMW and MMW PAHs from the