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OCCURRENCE OF ORGANIC POLLUTANTS: PAHs IN WATER BODIES AROUND KELANITISSA AND KERAWALAPITIYA POWER PLANTS IN SRI LANKA

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds with more than one benzene ring formed due to natural processes such as forest fires and anthropogenic activities. These ubiquitous contaminants have gathered an interest due to their toxicity and carcinogenic activity. Exposure to PAHs has also been linked with cancer, cardiovascular disease and poor fetal development. PAHs are considered as persistent organic pollutants because of their stable chemical structure and inherent resistance to decomposition. In this study, the water bodies near two diesel fueled power plants in Sri Lanka i.e., Kerawalapitiya and Kelanitissa were selected to determine the presence of PAHs in surface water and its sediment. In the preliminary sampling rounds, the presence of PAHs were identified. With increased sample size, three sampling rounds were carried out. In addition to water and sediment from Hamilton canal and Sebastian canal, water samples from wells near both power plants were analyzed. PAHs in water samples were extracted to dichloromethane and analyzed by HPLC with UV-DAD (254 nm) and HPLC- FLD (excitation at 250 nm, emission at 410 nm). Sediment samples were pretreated before the analysis and then, PAHs were extracted to methanol by ultra-sonication. The presence of low, medium and high molecular weight PAHs in water and sediment samples obtained from both sites were detected. Total concentration of PAHs in surface water samples obtained from Sebastian canal during rainy season (April 2015),

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dry season (July 2015) and rainy season (June 2016) were 0.11-1.71 µg/L, 2.36-14.68 µg/L and 6.88 µg/L - 10.05 µg/L, respectively. Furthermore, PAH content in water samples obtained from Hamilton canal during rainy season (April 2015), dry season (July 2015) and rainy season (April 2016) were 0.16-2.74 µg/L, 11.06- 54.89 µg/L and 5.35 - 7.79 µg/L, respectively. Well water samples obtained from Kelanitissa (W1) and Kerawalapitiya (W3) showed the presence of high amounts of BaP (0.025 µg/L) and BkF (0.339 µg/L) respectively which are higher than the guideline values for BaP (0.01 µg/L) and BkF (0.1 µg/L) according to European Unions' drinking water standards.The total PAH amount in surface water in both sites were higher in dry season than that of in rainy season. This may due to accumulation of PAHs over the time in water bodies around diesel fueled power stations during dry seasons due to lack of water flow. By investigating more dry and rainy seasons, an accumulation trend can be identified to address the seasonal variation of PAHS in water bodies.

Keywords: PAH, Kelanitissa, Kerawalapitiya, Seasonal variation, Sediment, Organic pollutant

INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are a diverse and ubiquitous class of chemical contaminants present in the environment. These PAHs are emitted as a result of carbonization and incomplete combustion of organic matter. Incomplete combustion of fossil fuels for industrial plants, heating and diesel powered motor vehicles, combustion sources inside house and workplaces are some sources of PAHs to the environment (Masih, 2012). These PAHs are also identified as semi-volatile organic compounds (SOCs) (Sehili and Lammel, 2007) and class of persistent organic pollutants (POPs) due to their increased resistance to oxidation and degradation with high molecular weights (Abdel-Shafy and Mansour, 2015). An increased attention has been given on PAHs since some of them are known to be mutagenic or carcinogenic (Ross and Nesnow 1999; Salamone *et al.,* 1979).

According to Europe Union and United States Environmental Protection Agency (US EPA), sixteen PAHs act as "priority pollutants" with different levels of risks in cancer (Lerda, 2010). The presence of PAHs is noted in air, soil, vegetation, ice, and water. PAHs originated from one place can be transported to another by the means of long-range atmospheric transport. As a result of their characteristics of lower water solubility, low vapor pressure, low reactivity they exist in both gas and particulate phases (Park *et al*., 2002). The fate and the potential of Long-Range transport of PAHs in atmosphere is greatly influenced by the partitioning between gas and particulate phases. Usually, PAHs with low molecular weight (i.e., 2-3 aromatic rings) are in equilibrium with particulate phase and gas phase whereas high molecular weight PAHs consisting of more (i.e., 4-6 aromatic rings) are mainly in the particulate phase (Wu *et al.,* 2006). PAHs in the atmosphere can be subjected to degradation and deposition.

The PAHs can reach water bodies mainly through dry and wet deposition, road runoff, industrial wastewater, leaching from creosote-impregnated wood, petroleum spills, and fossil fuel combustion. Because of their hydrophobic properties, PAHs in aquatic environments also rapidly become associated with the particulate matter. This causes the occurrence of PAHs in sediment of water bodies (Patrolecco *et al*., 2010). In rivers, sediment act as a storage compartment for PAHs. Therefore, by estimating the amounts of PAHs in the environment, the level of organic contamination can be identified (Mastran *et al*., 1994).

Several studies have been conducted worldwide in pursuit of determining the level of pollution in coastal areas and inland lakes (Karyab *et al*., 2013; Patrolecco *et al*., 2010; Lai *et al*., 2011). In Sri Lanka, studies have been performed to monitor the occurrence of PAHs in Bolgoda Lake, Beira Lake and Weras Ganga located in Western province. Phenanthrene and Pyrene had been identified in the northern end of Weras Ganga by using fish species Nile Tilapia (*Oreochromis niloticus*) as a biomarker (Pathiratne *et al.,* 2010). Sediment and water samples from Bathalagoda reservoir also have been studied and the PAH amount has been identified as lower than that of Beira lake.

In this study, the main objective was to identify the presence of PAHs in water bodies and its sediment around Kelanitissa and Kerawalapitiya power stations and to quantify them. AES Kelanitissa power station and Kerawalapitiya power stations are diesel fuel fired combine cycle powered power stations. As most of the PAHs in urban environments are pyrogenic in origin, there is a huge possibility of finding PAHs near the two power stations. Therefore, surface water samples and sediment samples from Hamilton canal near Kerawalapitiya power station and Sebastian canal near Kelanitissa power station were tested for the presence of PAHs. In order to confirm the atmospheric deposition of PAHs to water bodies, water samples from few wells close to each power station were tested.

The abbreviations used for the 16 PAHs are as follows: Naphthalene: **Nap**; Acenaphthylene: **Acy**; Acenaphthene: **Ace**; Fluorene: **Flu**; Phenanthrene: **Phe**; Anthracene: **Ant**; Fluoranthene: **Fth**; Pyrene: **Pyr**; Chrysene: **Chr**; Benz(a)anthracene: **BaA**; Benz(k)fluoranthene: **BkF**; Benz(b)fluoranthene: **BbF**; Benzo(a)pyrene: **BaP**; Dibenz(a,h)anthracene: **DahA**; Indenol(1,2,3-c,d)pyrene: **IcdP**; Benz(g,h,i)perylene: **BghiP**

METHODOLOGY

Chemicals

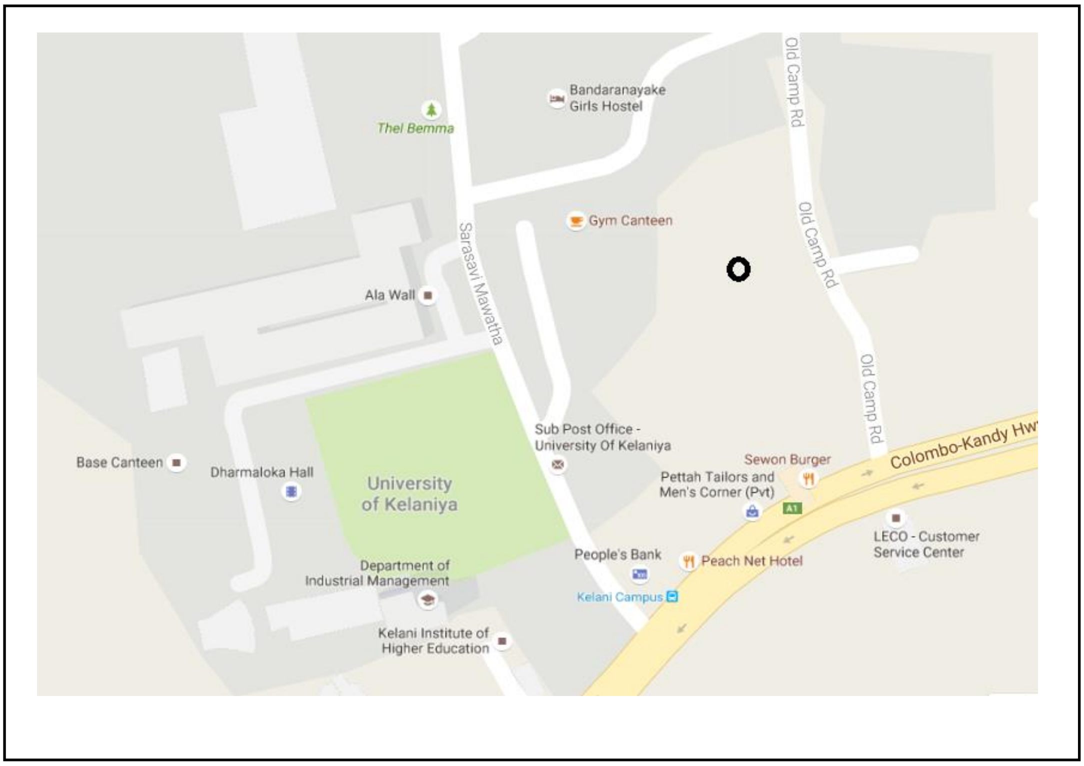
Dichloromethane (Sigma-Aldrich, Germany. Fischer Scientific, USA), methanol (BDH Prolabo, UK), anhydrous sodium sulfate (SigmaAldrich, Germany), HPLC grade acetonitrile (Sigma-Aldrich, Germany. Fischer Scientific, USA), silica gel (100- 200 Mesh, Fischer Scientific, India), standards of 16 PAHs (Supelco, 4-8734U EPA 610 PAH standard mix, Sigma-Aldrich, Germany). Methanol and dichloromethane were distilled prior to use.

Apparatus

Rotary evaporator (BUCHI R114, Switzerland), thermometer, centrifuge machine (Yider Technology Co.Ltd. Model DSC-200A-1), HPLC - UV DAD and fluorescence system (Agilent 1200 series, USA), VYDAC C-18 PAH column (The Nest Group, USA) (length 250 mm, internal diameter 4.6 mm, particle size 5 µm), Ultra-sonic cleaner (Soner 203H, Taiwan), Borosilicate glass column (length 30.0 cm, internal diameter 1.5 cm, Fischer Scientific, UK), UV-visible spectrophotometer (Agilent Cary 60, USA).

Description of sampling sites

Sampling was done in two sampling site; Sebestain canal close to Kelanitissa power plant and Hamilton canal close to Kerawalapitiya power plant. First round of sampling was done on 24th April 2015 i.e., soon after the inter monsoon season, second sampling was done on 30th July 2015 during the dry season. Next, the third sampling was done on 7th April 2016 at Kerawalapitiya and on 16th June 2016 around Kelanitissa power plant. The background level of PAHs was determined using a well water sample obtained from a well close to University of Kelaniya where the anthropogenic activity is relatively lower than the other two sampling sites. The site was 6-8 km and 3-6 km away from the sampling site 1 and sampling site 2, respectively.



Sampling site –○ **Figure 1: The Map of Reference site**

"GoogleMaps"[Online].https://www.google.lk/maps/@6.9744776,79.9175931,15.47z [Accessed: 4-Jul-2016].

Sebastian canal is found around Kelanitissa power station which is located in Peliyagoda, Western Province, Sri Lanka. The estimated terrain elevation above sea level is 11 meters. It is a highly industrialized area with high traffic emission. The Hamilton Canal which is located close to (i.e., within 2 km radius) the Kerawalapitiya power plant in Western Province Sri Lanka. The sampling sites of Hamilton canal is within the perimeter of 2 km from the Kerawalpitiya power station. Surface water and sediment samples were collected from the canal within a radius of 2.5 km.

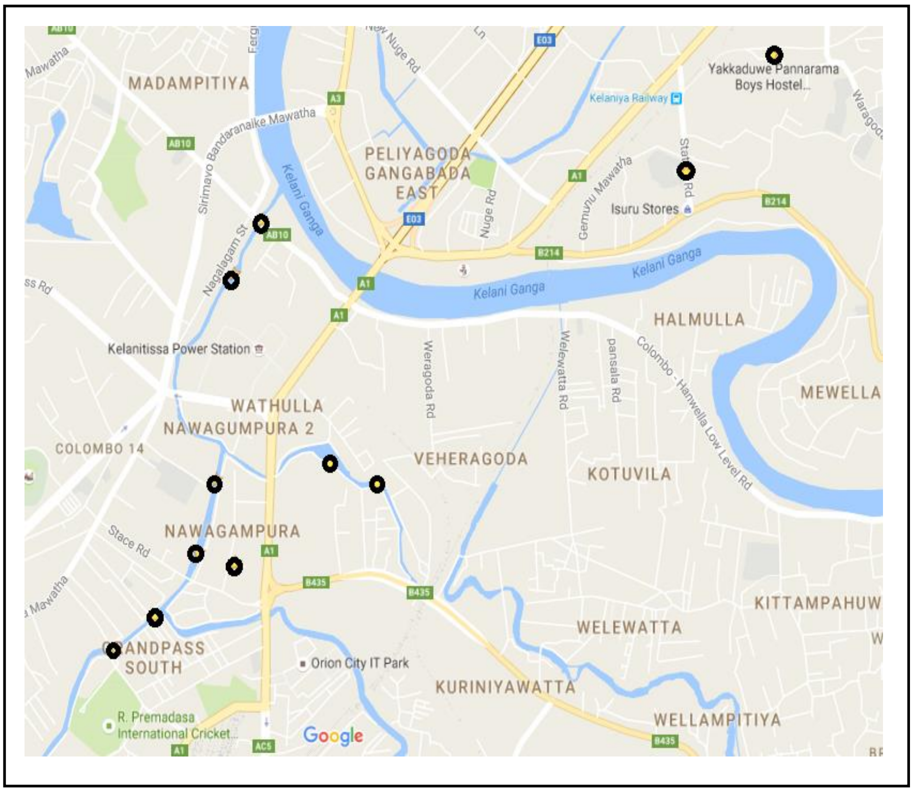


Figure 2: Map of sampling site 1

“GoogleMaps”[Online].https://www.google.lk/maps/@6.9507692,79.8809553,15z [Accessed: 4- Jul-2016]

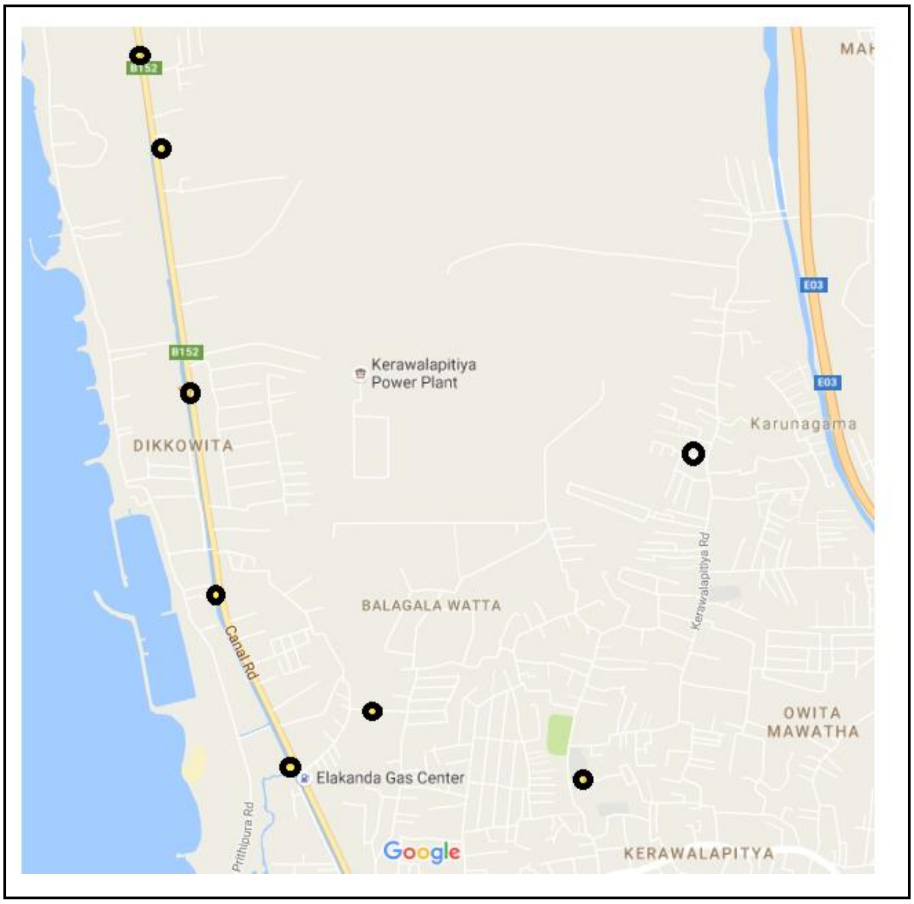


Figure 3: Map of sampling site 2

“GoogleMaps”[Online].https://www.google.lk/maps/@6.9517278,79.875555,15.99z [Accessed: 4-Jul-2016]

Sample Collection

Surface water samples close to the bank were collected from each site to amber bottles. In the first and second sampling round in 2015, 4 sub-sites were selected from each site for water and sediment sampling. In the third sampling round in 2016, eight sub-sites from Sebastian canal and five sub-sites from Hamilton canal were selected.

Five liters from each sub-site were collected. At each sampling point in Hamilton and Sebastian canals, the approximate flow rate was measured. Sediment samples containing soil at a thickness of 2.0-5.0 cm were collected to labelled containers by using a Peterson grab sampler. At each site, the depth from the surface was noted. Sediment sampling was done at the same location where the water sampling was done and stored under 10 ˚C until the extraction.

Sample Preparation

Water samples (2.0 L) were extracted using dichloromethane (3 x 50.0 mL) after filtration to remove any solid particles (Durchmesser 250 mm rundfilter). The extract was concentrated by rotary evaporation to about 0.05 mL and stored at 10 ˚C until analysis. Sediment samples were air dried to about 2-3 days and soil particles were removed by sieving (250 microns). Sediment (1.00 g) was weighed into an amber glass bottle and distilled methanol (10.00 mL) was added (http://www.epa.ohio.gov/portals/35/guidance/sedman2001.pdf [1/04/2016])

The samples were sonicated at 50˚C for 1 hour. In order to further purify extracts from sediment samples, a cleanup procedure was performed. Methanol extract of sediments were concentrated into nearly 0.5 mL using the rotary evaporator. The residue was prepared for column chromatography by dissolving in dichloromethane (2.00 mL). Silica column chromatography was performed to remove the interferences before the HPLC analysis (Stationary phase- Silica, mobile phase- dichloromethane). Fractions (10.0 mL each) were collected until the absorbance at 254 nm was constant. Next, similar fractions were combined and evaporated to dryness by rotary evaporation. Subsequently, the residues dissolved in Acetonitrile (0.05 mL) were stored at 10 ˚C after filtering through 0.45 micron PTFE syringe filters.

Analytical procedure

Water and sediment sample were analyzed for PAHs including EPA priority pollutants using HPLC system (Agilent 1200 series) with UV-DAD (254 nm) and Fluorescence (excitation: 250 nm, emission: 410 nm) detectors. The revered phase column chromatography was done using VYDAC C-18 PAH column. Acetonitrile: water (using a gradient program, Table 1.) was used as the mobile phase at 0.5 mL min^{-1} flow rate. A gradient method that began from 55:45 of acetonitrile and water was applied. Then, the proportion of acetonitrile was gradually increased up to 100:0 by a binary pump (Agilent 1200 series). After that, each sample (20 µL) was injected and HPLC traces were obtained.

Table 1: HPLC profile for PAH analysis

Time (min)	Conditions	Flow
0.00	55% CH_3CN 45% water	0.5 mL/min
3.00	55% CH_3CN 45% water	0.5 mL/min
10.00	100% CH_3CN 0% water	0.5 mL/min
24.00	100% CH_3CN 0% water	0.5 mL/min
24.10	55% CH_3CN 45% water	0.5 mL/min
30.00	55% CH_3CN 45% water	0.5 mL/min

Standard mixture of 16 PAHs were used for the identification and the quantification. Three concentrations of each standard compound were prepared in acetonitrile. Each standard (20 µL) was injected and HPLC chromatograms were obtained using above mentioned conditions and those were used to construct external calibration for each PAH. The presence of PAHs in the samples was identified by the retention time of authentic PAHs standards. The identified PAHs were quantified using the external calibration method.

A recovery study was done for surface water samples (900.0 mL) by spiking with fluoranthene (0.03 g/L, 22 µL) and anthracene (0.07 g/L, 10 µL). Then the resulted sample was extracted HPLC trace was obtained. Sediment samples (2.50 g) were spiked with fluoranthene (0.03 g/L, 22 µL) and anthracene (0.07 g/L, 10 µL). Then the resulted samples were extracted and HPLC traces were obtained. Minitab 16.2.3 software was used for the statistical analysis.

RESULTS AND DISCUSSION

Surface water samples

Preliminary studies show the occurrence of PAHs in water bodies close to power plants. Since the first-round of sampling was done immediately after rainy season, another set of samples were collected from the water bodies during dry season of the year. Likewise, three rounds of sampling were carried out to monitor the seasonal variation. The concentrations of individual PAHs in water samples obtained from Hamilton canal and Sebastian canal are displayed in Tables 2 and 3.

Table 2: Concentrations of measured PAHs in water samples from Kerawalapitiya (April 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	1.27	2.39	BLSC	BLSC	BLSC	BLSC	0.84	0.65
Fth	0.15	0.2	ND	ND	0.09	0.11	0.08	0.17
Flu	ND	ND	BLSC	BLSC	ND	ND	ND	ND
Ant	0.09	0.15	ND	ND	0.07	0.1	0.15	0.17
Pyr	BLSC	BLSC	ND	ND	ND	ND	0.38	0.42
Phe	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC

Table 3: Concentrations of measured PAHs in water samples from Kelanitissa (April 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC	BLSC
Flu	0.21	0.25	0.09	0.16	0.07	0.15	BLSC	BLSC
Ant	BLSC	BLSC	0.02	0.03	0.01	0.02	BLSC	BLSC

[1] ND- Not detected

[2] BLSC- Below lowest standard concentration

Total concentration of PAHs in surface water samples obtained from Sebastian canal during rainy season (April 2015), dry season (July 2015) and rainy season (June 2016) were 0.11-1.71 µg/L, 2.36-14.68 µg/L and 6.88 µg/L - 10.05 µg/L, respectively (Table 4). Furthermore, PAH content in water samples obtained from Hamilton canal during rainy season (April 2015), dry season (July 2015) and rainy season (April 2016) were 0.16-2.74 µg/L, 11.06- 54.89 µg/L and 5.35 - 7.79 µg/L, respectively (Table 5).

Table 4: Total measured PAH concentration in water samples from Kerawalapitiya.

Season	Concentration/ µg L^{-1}
April 2015	0.16- 2.74
July 2015	11.06- 54.89
June 2016	5.35- 7.79

Table 5: Total measured PAH concentration in water samples from Kelanitissa.

Season	Concentration/ µg L^{-1}
April 2015	0.11- 1.71
July 2015	2.36- 14.68
June 2016	6.88- 10.05

The detail results of water sample analysis from Kerawalapitiya and Kelanitissa for different seasons were given in Tables 6 – 9. The data shows high PAH content in surface water samples from Hamilton canal (water body close to Kerawalapitiya power plant) than Sebastian canal (water body close to Kelanitissa power plant). When comparing the PAH content in each sampling rounds, the concentrations of total measured PAHs varied greatly. Similar variation has been studied in Iran, in which it is reported that during summer the PAHs concentration in water is high than in winter. Results of this study are much higher than those detected by Karyab *et al.,* 2013. This may happen because in the rainy season, PAHs deposited on to surface water may have been washed away. In addition, due to their lipophilicity PAHs bound to particulate matter present in surface water can sediment. During dry season, disturbance of surface of water bodies is low. Although Sebastian canal is an almost stagnant water body and Hamilton canal is used by local fishermen for their transportation, surface water from Hamilton canal which is more susceptible to turbulence showed higher amounts of PAHs.

Water samples taken from both Hamilton and Sebastian canals during the first two sampling rounds indicated the presence of low-molecular weight PAHs like Napthalene, Acenaphthene, Acenaphthylene, Fluorene and Anthracene. But in water samples obtained during the third sampling round, in addition to low molecular weight PAHs, the presence of high molecular weight and medium molecular weight PAHs was noted. Low molecular weight PAHs having low vapour pressure are mostly in gaseous phase which travels a long distance away from the source. High molecular weight PAHs can easily adsorb onto particles and probably be deposited near the source.

Hamilton canal is located a 2 km away from the Kerawalapitiya power plant and other possible industrial sources. Moreover, since it is in a sub-urban area the vehicular emission of pollutants is minimum compared to Sebastian canal. The results from the first two sampling rounds show an increase in measured PAHs for both the sites, with increasing distance from the source. In order to observe the effect of distance from the source to the PAH content, the number of samples was increased during the third sampling round (April 2016 and June 2016).

To identify whether the possible source of PAHs to the surface of water bodies might be due to atmospheric deposition, well water samples were analyzed by using the same procedure.

Table 6: Concentrations of measured PAHs in water samples from Kerawalapitiya (July 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	3.35	1.6	2.79	18.36	7.93	26.4	23.57	26.97
Acy	3.46	6.79	BLSC	BLSC	2.41	9.96	0.87	14.87
Ace	9.97	20.17	8.27	8.84	3.56	10.00	10.00	11.19
Flu	BLSC	BLSC	ND	ND	ND	ND	0.29	0.45
Ant	ND	ND	ND	ND	0.02	0.04	0.04	0.05
B[a]A	0.5	0.59	BLSC	BLSC	0.08	0.36	0.36	0.42
Fth	ND	ND	BLSC	BLSC	0.16	0.89	0.6	0.89
Chr	ND	ND	ND	ND	BLSC	BLSC	0.05	0.06

Table 7: Concentrations of measured PAHs in water samples from Kelanitissa (July 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	2.65	3.98	6.1	7.63	1.11	2.64	0.74	5.09
Ace	0.98	2.27	ND	ND	BLSC	BLSC	0.68	8.44
Flu	ND	ND	0.41	0.44	BLSC	BLSC	BLSC	BLSC
Fth	ND	ND	0.27	0.36	0.49	0.65	0.49	0.53
Pyr	ND	ND	0.40	0.81	0.76	0.90	0.50	0.62
B[a]A	ND	ND	0.05	0.06	BLSC	BLSC	BLSC	BLSC
B[k]F	0.14	0.19	0.13	0.14	ND	ND	ND	ND

Table 8: Concentrations of PAHs in the water samples from Kerawalapitiya (April 2016).

PAH	Concentration of PAHs (µg/L)									
	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
	A	B	A	B	A	B	A	B	A	B
Nap	0.154	BLSC	0.704	1.160	0.37	0.37	ND	ND	BLSC	BLSC
Fth	ND	ND	ND	ND	BLSC	0.015	ND	ND	ND	ND
Ace	1.778	BLSC	ND	ND	BLSC	ND	0.303	1.522	1.318	1.546
Flu	BLSC[2]	BLSC	0.129	ND	0.039	BLSC	0.034	0.084	0.054	0.044
Ant	0.133	0.604	ND	ND	BLSC	0.003	ND	ND	BLSC	BLSC
Pyr	ND	ND	BLSC	BLSC	ND	ND	ND	ND	ND	ND
Phe	0.012	BLSC	0.008	BLSC	BLSC	0.022	0.007	0.006	BLSC	0.012
B(k)F	0.003	0.009	0.017	ND	0.02	BLSC	0.022	ND	0.018	0.022
B(ghi)P	ND	ND	BLSC	0.154	ND	ND	ND	ND	ND	ND
B(a)P	ND	ND	ND	ND	BLSC	BLSC	ND	ND	ND	ND
B(b)F	ND	ND	ND	ND	0.01	BLSC	0.017	BLSC	ND	ND
Chr	ND	ND	BLSC	BLSC	ND	ND	ND	ND	ND	ND

Table 9: Concentrations of PAHs in the water samples of Sebastian canal, Kelanitissa (June 2016).

PAH		Nap	Ace	Flu	Ant	Pyr	Phe	B(k)F	B(b)F	B(a)A	Fth	Acy	Chr
Measured PAH concentration range (µg/L)	1A	ND	BLSC	ND	0.006	ND	BLSC	ND	0.019	BLSC	ND	ND	ND
	1B	ND	BLSC	BLSC	BLSC	ND	BLSC	ND	0.021	0.01	0.134	ND	ND
	2A	0.676	ND	0.021	0.004	ND	ND	ND	0.019	0.009	BLSC	ND	ND
	2B	0.224	ND	BLSC	0.004	ND	ND	ND	0.026	0.009	0.156	ND	ND
	3A	ND	ND	BLSC	BLSC	ND	ND	0.004	ND	0.016	0.123	ND	ND
	3B	ND	ND	BLSC	BLSC	ND	ND	ND	0.004	ND	0.002	ND	ND
	4A	ND	0.696	ND	0.004	ND	ND	ND	0.016	ND	ND	ND	BLSC
	4B	ND	0.366	ND	BLSC	ND	ND	ND	0.011	ND	ND	ND	ND
	5A	0.208	0.614	BLSC	0.016	0.016	BLSC	ND	0.018	0.019	0.024	0.72	0.037
	6A	0.217	BLSC	BLSC	0.006	ND	ND	ND	0.024	BLSC	ND	ND	ND
	6B	BLSC	ND	ND	BLSC	ND	ND	ND	0.024	ND	ND	ND	0.083
	7A	ND	0.233	BLSC	ND	BLSC	BLSC	ND	0.033	BLSC	ND	ND	0.025
	7B	ND	ND	0.039	BLSC	ND	0.043	ND	0.011	ND	ND	0.722	ND
	8A	0.129	1.778	0.127	0.134	ND	ND	ND	0.028	0.009	0.072	1.41	0.071
	8B	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.51	ND

Well water samples

Well water samples obtained from both Hamilton canal and Sebastian canal showed the presence of all three types of PAHs. The presence of relatively high amounts of PAHs in drinking water can lead to serious health effects in humans. The allowable level of PAHs in Europe Unions' drinking water standard is 0.01 µg/L for BaP and 0.1 µg/L for carcinogenic PAHs.
(http://www.fsai.ie/uploadedFiles/Legislation/Food_Legisation_Links/Water/EU_Directive_98_83_EC.pdf. [22/02/2017])

W1 samples obtained near Kelanitissa plant showed higher values (0.025 µg/L) than the guideline value for BaP which is a carcinogenic PAH (Figure 4). W3 samples obtained near Kereawalapitiya plant also contained higher amount of BkF (0.339 µg/L) than the guideline value (Figure 5). BkF is listed as a probable carcinogenic PAH by the US EPA (Lerda, 2010). In this study all the well water samples were taken from wells used by public for their household purposes including drinking and bathing. Therefore, the presence of these carcinogenic PAHs might pose a serious health issue.

Table 10: **Concentrations of PAHs in the well water samples taken around the Kelanitissa power plant.**

PAH	Concentration of PAHs (µg/L)					
	W1A	W1B	W2A	W2B	W3A	W3B
Nap	BLSC	ND	ND	ND	ND	ND
Acy	0.285	ND	ND	ND	0.347	1.815
Flu	BLSC	0.18	BLSC	0.004	0.108	0.266
Phe	0.007	ND	ND	ND	0.006	0.032
Ant	BLSC	ND	0.003	0.231	0.087	0.033
Fth	BLSC	BLSC	ND	ND	ND	BLSC
Pyr	0.056	BLSC	ND	ND	BLSC	0.013
B(a)A	0.015	0.017	0.016	0.009	BLSC	ND
B(b)F	BLSC	0.063	0.036	0.012	0.014	ND
B(a)P	0.025	0.007	0.002	BLSC	ND	0.066
Ace	ND	0.574	ND	ND	ND	ND
Chr	ND	0.076	0.054	BLSC	0.06	ND

Table 11: Concentrations of PAHs in the well water samples taken around the Kerawalapitiya power plant.

PAH	Concentrations of PAHs (µg/L)					
	W1A	W1B	W2A	W2B	W3A	W3B
Nap	BLSC	0.181	ND	ND	ND	BLSC
Ace	0.421	0.228	ND	ND	ND	ND
Acy	0.322	ND	0.979	0.979	ND	ND
Phe	BLSC	ND	ND	ND	0.237	BLSC
Fth	0.013	ND	ND	ND	BLSC	BLSC
B(a)A	0.008	ND	BLSC	BLSC	ND	ND
B(b)F	0.025	ND	ND	ND	BLSC	0.023
B(k)F	0.005	0.019	0.018	BLSC	0.339	BLSC
Pyr	BLSC	ND	ND	ND	ND	ND
Flu	ND	0.021	BLSC	BLSC	ND	0.215
B(g,hi)P	ND	ND	BLSC	0.831	BLSC	0.624
Ant	0.006	0.695	0.05	BLSC	BLSC	0.195

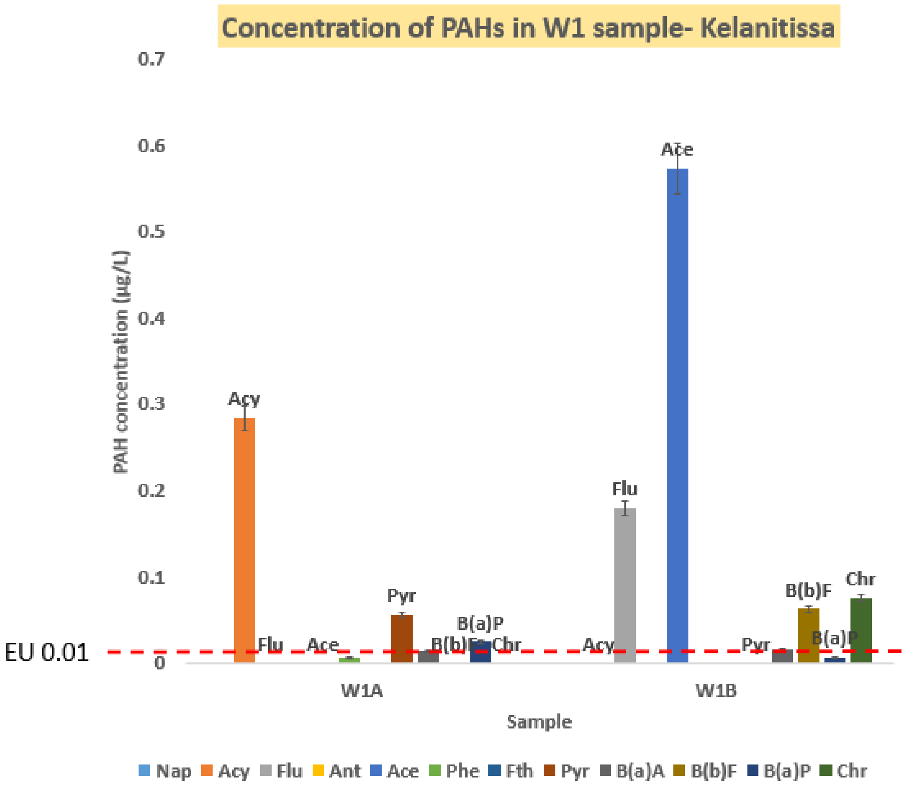


Figure 4: Concentration of individual PAHs in W1 sample- Kelanitissa.

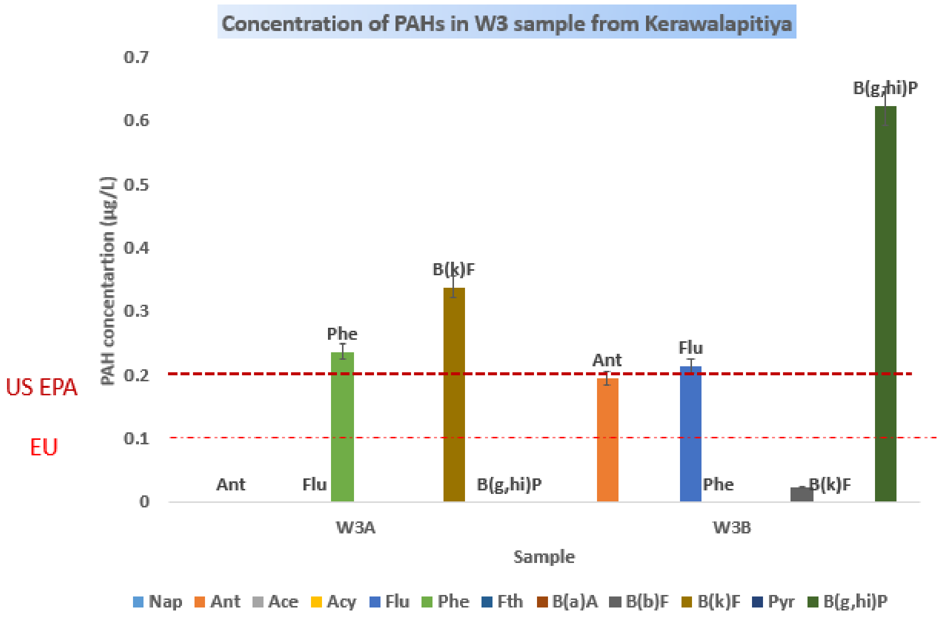


Figure 5: Concentration of individual PAHs in W3 sample- Kerawalapitiya.

Sediment

For the purposes of water quality monitoring, qualitative and quantitative studies of sediment is important. Various studies have established methods to extract PAHs from sediment. Generally, the concentrations of PAHs in sediments of a water body are much higher than that in the water column in contact. According to a previous study, the dissolved PAH concentrations in the water column of Slave river, Canada, is above the analytical detection limits only in very few cases, whereas their concentrations in suspended sediment often exceeded the lowest effective level according to Ontario Sediment Quality Guidelines (McCarthy *et al.*, 1997).

Total PAH concentration in sediment samples ranged from 1.53 – 3.89 µg kg^{-1} in Sebastian canal (table 12) and from 0.68 – 21.60 µg kg^{-1} in Hamilton canal (Table 13) in July 2015.

Table 12: Total measured PAH concentration in sediment samples from Kerawalapitiya.

Season	Concentration/ µg kg^{-1}
July 2015 (Dry)	0.68- 21.60
June 2016 (Rainy)	31.75- 90.89

Table 13: Total measured PAH concentration in sediment samples from Kelanitissa.

Season	Concentration/ µg kg^{-1}
July 2015 (Dry)	1.53- 3.89
June 2016 (Rainy)	70.69 – 114.94

Higher concentrations of PAH were given by sediments obtained during June 2016- rainy season. Detail results are shown in Table 14 and Table 15. This amount is higher than those detected by Baumard *et al.,* 1998. However, a similar pattern was observed here as the total dissolved PAHs in surface water is lower than the particulate PAHs in sediment in Seine River (Motelay-Massei *et al*., 2002).

Table 14: Total measured PAH concentration in sediment samples from Kerawalapitiya (July 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	2.94	3.42	0.41	1.29	0.39	1.6	ND	ND
Acy	5.46	9.84	ND	ND	4.94	5.47	5.95	6.9
Fth	1.76	2.01	ND	ND	ND	ND	0.51	0.75
Ace	2.76	3.55	ND	ND	4.94	5.47	5.95	6.9
Flu	0.83	1.56	0.21	0.22	0.17	0.75	0.21	0.22
Ant	0.41	0.64	0.03	0.04	ND	ND	0.16	0.2
Pyr	ND	ND	ND	ND	ND	ND	0.99`	1.49
Phe	ND	ND	0.03	0.09	0.16	1.73	0.29	0.45
B(a)A	0.52	0.56	ND	ND	0.45	0.51	ND	ND

Table 15: Total measured PAH concentration in sediment samples from Kelanitissa (July 2015).

PAH	Concentration of PAHs (µg/L)							
	Sample 1		Sample 2		Sample 3		Sample 4	
	A	B	A	B	A	B	A	B
Nap	0.73	0.84	ND	ND	0.72	0.89	0.74	0.79
Ace	4.51	6.58	4.78	5.26	2.74	3.53	2.18	6.42
Phe	0.09	0.32	BLSC	BLSC	ND	ND	0.03	0.28
B(a)A	ND	ND	0.10	0.16	0.14	0.17	0.11	0.30

Recovery studies for both water and sediment samples were done using a low molecular weight PAH (Anthracene) and a medium molecular weight PAH (Fluoranthene).

Table 16: Recovery percentages of PAHs in water and sediment samples.

PAHs	Sediment%	Water %
Anthracene	80	58
Fluoranthene	106	63

CONCLUSION

According to the results, there was a variability in the concentrations of the measured PAHs over the seasonal change. During rainy season of the year, the quantities of PAHs detected at each sampling sites were low. The total concentration of PAHs in surface water samples obtained from Sebastian canal during rainy season (April 2015), dry season (July 2015) and rainy season (June 2016) were 0.11-1.71 µg/L, 2.36-14.68 µg/L and 6.88 µg/L - 10.05 µg/L, respectively.

For most of the samples, the measured PAH concentration for sediment was higher than that of the surface water. The concentration of Total measured PAHs in sediment samples obtained from Kerawalapitiya was 0.68 – 21.60 µg/L (July 2015) and 31.75 - 90.89 µg/L (June 2016). The concentration of total measured PAHs in sediment samples obtained from Kelanitissa ranged from 1.53- 3.89 µg/L (July 2015) 70.69 – 114.94 µg/L (June 2016).

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