

Polycyclic Aromatic Hydrocarbons (Pahs) in Some Plant Species at West Qurna-1 Oil Field in Basra, Southern Iraq

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Abstract

Concentrations and sources of Polycyclic aromatic hydrocarbons were determined seasonally in some terrestrial plant species (*Conocarpus lancifolius*, *Eucalyptus camaldulensis* and *Suaeda vermiculata*) at three stations in west Qurna-1 oil field, southern Iraq during the period from January 2018 to December 2018. The results showed that the highest mean concentration of PAHs in plant species at DS6 was (2.813 ng/g dry weight) in *E. camaldulensis* and the lowest was in *C. lancifolius* (2.106 ng/g dry weight). Seasonal variation of PAHs concentration showed that the highest mean concentration was recorded in spring (2.634 ng/g dry weight) in *E. camaldulensis* while the lowest mean concentration was recorded in winter (1.975 ng/g dry weight) in *Suaeda vermiculata*. According to the PAHs indices [(The Fluoranthene/Pyrene ratio, Phenanthrene/Anthracene ratio, LMW/HMW ratio, Ant/(Ant+Phen) ratio, BaA/(BaA+Chry) ratio and InP/(InP+BghiP) ratio)], the main sources of PAHs in these plants species were pyrogenic and petrogenic.

Keywords: PAHs, Plant species, Oil field, Iraq

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) exist in the environment, and they are distributed in both aquatic and terrestrial environments and both biogenic and anthropogenic origin. They can be formed by several pathways: biosynthesis, pyrogenic and petrogenic (Karem, 2016).

Petrogenic PAHs are derived from petroleum and other fossil fuels containing PAHs. Diagenetic PAHs refer to PAHs formation from biogenic precursors, like plant terpenes, leading to the formation of compounds, such as retene (methyl isopropyl phenanthrene or 1-methyl-7-isopropyl phenanthrene C₁₈H₁₈) and derivatives of phenanthrene and chrysene. A potential fourth source of PAHs is biogenic or purely from bacteria, fungi, plants or animals in sedimentary environments without any contributions from diagnostic processes; however, this source is not significant. Their presence in all environment compartments results from both natural processes, such as volcanic activity or forest fires, and predominantly anthropogenic activities, including waste incineration, burning wood, coal or garbage, and operation of gasoline and diesel engines (Bakhtiari *et al.*, 2009). PAHs are very dangerous substances because of their cariogenic properties. It is important to know the features of PAHs transport and accumulation in soils, especially on agricultural lands. The PAHs are produced by combustion

of fossil fuel (coal and petroleum) and as a natural source released to the environment (Zakaria *et al.*, 2002).

They can be transported over long distances in the atmosphere and deposited in faraway areas; hence, they are widely found in the environment (Wang *et al.*, 2015). There are a large number of PAH compounds in the environment, comprising of sixteen compounds of increasing environmental and health interests: naphthalene, acenaphthylene, acenaphene, phenanthrene, fluorene, anthracene, fluoranthene, pyrene, chrysene, benzo (a) anthracene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, benzo (ghi) perylene, dibenzo (ah) and anthracene, indeno[1,2,3(cd)] pyrene. The physical, chemical and toxicological properties for each of these compounds are different. Therefore, their evaluation in nature is required (Al-Hejuje *et al.*, 2015).

Long-term exposure to hydrocarbon compounds can negatively impact human life in terms of comfort and health (Al-Hejuje *et al.*, 2015). PAHs may largely contaminate all environmental matrices and raise toxicological, mutagenic, and carcinogenic concerns (Karem, 2016).

The aim of the present study is to determine the levels of PAH compounds in some plant species at west Qurna-1 oil field in Basra, southern Iraq by collecting, extracting and analysing the aromatic compounds in the plant samples.

Study Area

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The super-giant west Qurna oil field in southern Iraq is located in Basra Governorate, around 65 km northwest of the city of Basra. The west Qurna field is situated in a long, sinuous North South trending structure. The field is comprised of two separate license areas, 1 and 2. The west Qurna field was discovered in August 1973 and a total of

early to late Cretaceous Sa'di, Khasib, Mishrif, Zubair, Ratawi and Yamama formations, and gas condensate was recovered from a tesin the late Jurassic Najmah formation.

West Qurna-1 oil field is located southwest of Basra city. The study area extended between latitudes (30° 45' 35'' E, 30° 52' 54'' N) and longitude (47° 19' 12'' E, 47°

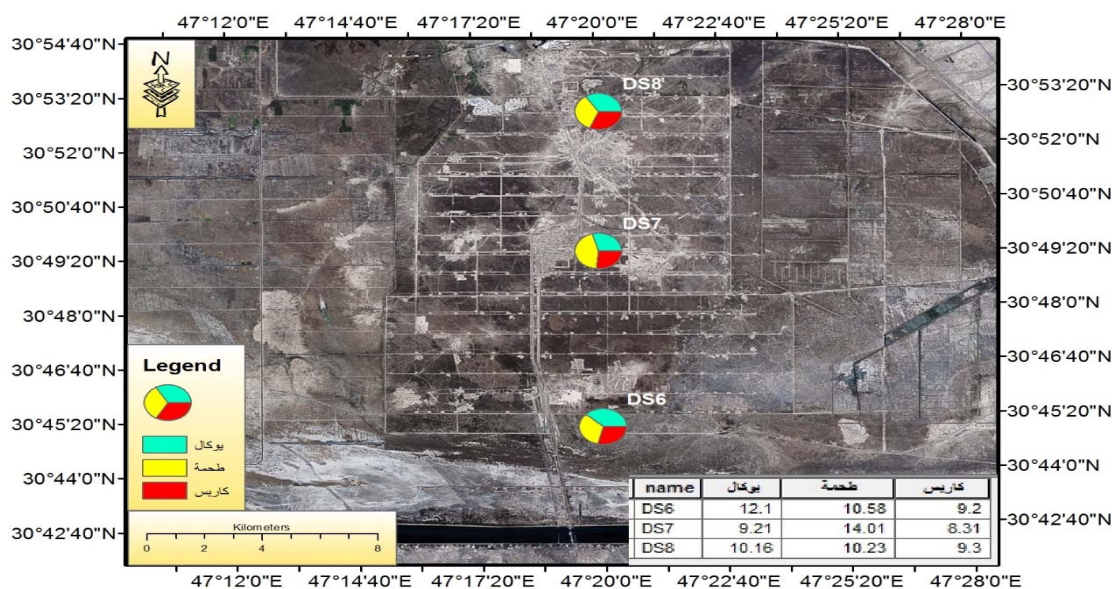


Figure 1. The study area in west Qurna-1 oil field.

13 wells have been drilled in the West Qurna-1 area. Significant oil accumulations have been discovered in the

19' 53'') as shown in Fig 1. The west Qurna oil field area is characterized by a flat topography, where the elevation of the overall study area ranges from 0.5 m to 2 m above sea level.

2. Materials and Methods

Three species of plants (*Conocarpus lancifolius*, *Eucalyptus camaldulensis* and *Suaeda vermiculata*) were chosen. The plants leaves samples were collected by hand from three stations (DS6, DA7 and DS8) seasonally during the period from January 2018 to December 2018. The plant samples were washed with distilled water, dried at room temperature, ground finely in an electrical mortar, and stored in glass containers until analysis. Five grams of each ground plant samples were placed separately in soxhlet using soxhlet intermittent extraction (Goutex and Saliot, 1980) with 120 ml mixed solvents methanol:benzene (1:1 v/v) for 24-36 hr at a temperature that did not exceed 40°C. At the end of this period, the combined extracts underwent saponification for 2 hr by adding 20 ml 4M MeOH(KOH) at the same temperature and cooled to room temperature, and the saponification matter with 40 ml n-hexane was extracted using a separator funnel. The extract was then concentrated to about 2 ml by a rotary evaporator for the following clean-up. The concentrated extract was fractionated by column chromatography on anhydrous sodium sulphate (1 g) over alumina (10 g) and silica gel (10 g). The aromatic hydrocarbons were obtained by successively eluting Benzen (25 ml). The aromatic fractions were concentrated again on a rotary evaporator and transferred to a vial, and the volume was adjusted to 1 ml exactly using a stream of

nitrogen gas. An aliquot of 1 ml of aromatic hydrocarbons extract was subjected to analysis. The determination of PAHs was done by using HPLC (Shimadzu LC). A standard (PAHs) was used to determine the qualities and quantities of these compounds in the plant samples. The condition operation for HPLC was as follows: the column was C18 (250mm, 25cm, 4.6mm), the mobile phase was acetonitrile:water (90:10 v/v), the flow rate was 0.5ml/min, the injection volume was 20µl, the wavelength of UV/visible was 254 nm (Al-Hejuje, 2014; Al-Hejuje *et al.*, 2015).

3. Statistical Analysis

Analysis of Variance (One-way ANOVA) was applied using Statistical Package for Social Science (SPSS) ver.17.0 software to identify the existence of significant temporal and spatial differences (Al-Hejuje, 2014).

4. Results

The PAHs concentration in plants are classified as shown in Table 1-3.

Table 1. Concentrations of Polycyclic Aromatic Hydrocarbons (ng/g dry weight) in *C. lancifolius*.

PAHs	Winter			Spring			Summer			Autumn		
	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8
Naphthalene	0.109	0.138	0.134	0.114	0.146	0.143	0.120	0.164	0.152	0.116	0.151	0.141
Acenaphthylene	0.126	0.142	0.125	0.132	0.166	0.130	0.141	0.173	0.126	0.135	0.162	0.117
Acenaphene	0.043	0.150	0.108	0.042	0.143	0.116	0.024	0.021	0.112	0.011	0.016	0.062
Fluorene	0.148	0.121	0.127	0.152	0.138	0.130	0.153	0.142	0.131	0.148	0.135	0.125
Phenanthrene	0.122	0.117	0.133	0.124	0.125	0.148	0.110	0.131	0.152	0.102	0.122	0.130
Anthracene	0.167	0.109	0.177	0.177	0.215	0.227	0.198	0.233	0.249	0.173	0.197	0.213
Fluoranthene	0.112	0.155	0.175	0.117	0.262	0.212	0.221	0.225	0.225	0.175	0.194	0.210
Pyrene	0.129	0.115	0.228	0.132	0.127	0.254	0.211	0.101	0.320	0.167	0.100	0.299
Benzo(a) anthracene	0.115	0.102	0.109	0.113	0.013	0.114	0.121	0.011	0.030	0.126	0.042	0.037
Chrysene	0.117	0.113	0.210	0.113	0.139	0.227	0.117	0.146	0.214	0.112	0.135	0.196
Benzo(b) fluoranthene	0.297	0.124	0.137	0.310	0.175	0.154	0.325	0.198	0.163	0.210	0.168	0.142
Benzo(k) fluoranthene	0.118	0.130	0.106	0.124	0.165	0.113	0.126	0.071	0.022	0.115	0.066	0.113
Benzo(a) pyrene	0.021	0.121	0.118	0.024	0.233	0.126	0.125	0.259	0.133	0.117	0.221	0.115
Indo(1,2,3-cd) pyrene	0.018	0.133	0.175	0.021	0.147	0.216	0.119	0.152	0.236	0.100	0.134	0.201
Dibenzo anthracene	0.177	0.123	0.137	0.185	0.131	0.132	0.194	0.130	0.136	0.166	0.120	0.121
Benzo(g,h,i) perylene	0.057	0.036	0.125	0.064	0.054	0.247	0.173	0.173	0.263	0.153	0.144	0.195
Total	1.876	1.929	2.319	1.944	2.283	2.680	2.478	2.330	2.664	2.126	2.107	2.457

Table 2. Concentrations of Polycyclic Aromatic Hydrocarbons (ng/g dry weight) in *E. camaldulensis*

PAHs	Winter			Spring			Summer			Autumn		
	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8
Naphthalene	0.134	0.107	0.170	0.114	0.190	0.032	0.116	0.036	0.036	0.107	0.027	0.138
Acenaphthylene	0.125	0.114	0.125	0.114	0.138	0.186	0.210	0.215	0.218	0.194	0.192	0.194
Acenaphene	0.108	0.165	0.134	0.202	0.143	0.043	0.027	0.150	0.036	0.022	0.143	0.027
Fluorene	0.127	0.124	0.102	0.140	0.033	0.139	0.141	0.024	0.140	0.127	0.015	0.152
Phenanthrene	0.133	0.132	0.103	0.158	0.116	0.127	0.164	0.129	0.139	0.148	0.114	0.142
Anthracene	0.177	0.167	0.095	0.198	0.112	0.156	0.260	0.115	0.164	0.244	0.104	0.152
Fluoranthene	0.175	0.211	0.197	0.262	0.220	0.318	0.362	0.236	0.320	0.226	0.218	0.312
Pyrene	0.228	0.164	0.195	0.211	0.231	0.211	0.201	0.252	0.209	0.191	0.247	0.194
Benzo(a) anthracene	0.109	0.310	0.100	0.348	0.102	0.148	0.357	0.063	0.164	0.341	0.041	0.013
Chrysene	0.210	0.027	0.102	0.032	0.112	0.110	0.124	0.131	0.012	0.115	0.124	0.015
Benzo(b) fluoranthene	0.137	0.102	0.020	0.119	0.021	0.113	0.123	0.063	0.115	0.113	0.048	0.172
Benzo(k) fluoranthene	0.106	0.105	0.047	0.113	0.275	0.063	0.121	0.311	0.030	0.116	0.290	0.035
Benzo(a) pyrene	0.118	0.221	0.201	0.274	0.221	0.057	0.281	0.210	0.069	0.255	0.201	0.061
Indo(1,2,3-cd) pyrene	0.175	0.148	0.326	0.326	0.376	0.125	0.312	0.456	0.146	0.289	0.397	0.138
Dibenzo anthracene	0.137	0.131	0.304	0.137	0.317	0.072	0.142	0.326	0.056	0.133	0.311	0.074
Benzo(g,h,i) perylene	0.125	0.142	0.026	0.214	0.032	0.114	0.217	0.053	0.124	0.199	0.034	0.133
Total	2.319	2.370	2.247	2.962	2.639	2.302	3.152	2.770	1.978	2.820	2.506	1.952

Table 3. Concentrations of Polycyclic Aromatic Hydrocarbons (ng/g dry weight) in *S. Vermiculata*

PAHs	Winter			Spring			Summer			Autumn		
	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8	DS6	DS7	DS8
Naphthalene	0.117	0.095	0.120	0.127	0.106	0.131	0.142	0.035	0.225	0.126	0.028	0.193
Acenaphthylene	0.119	0.100	0.117	0.125	0.116	0.125	0.140	0.132	0.093	0.134	0.125	0.081
Acenaphene	0.149	0.126	0.093	0.142	0.143	0.113	0.173	0.138	0.115	0.157	0.127	0.104
Fluorene	0.102	0.147	0.113	0.036	0.162	0.124	0.046	0.172	0.127	0.035	0.155	0.110
Phenanthrene	0.116	0.134	0.120	0.136	0.167	0.141	0.129	0.186	0.142	0.111	0.160	0.132
Anthracene	0.123	0.129	0.135	0.127	0.147	0.160	0.147	0.153	0.173	0.134	0.141	0.153
Fluoranthene	0.147	0.110	0.128	0.135	0.115	0.148	0.198	0.035	0.259	0.167	0.220	0.237
Pyrene	0.131	0.194	0.056	0.117	0.201	0.088	0.172	0.210	0.092	0.158	0.191	0.071
Benzo(a) anthracene	0.032	0.122	0.112	0.110	0.021	0.120	0.032	0.011	0.113	0.026	0.015	0.106
Chrysene	0.125	0.127	0.024	0.126	0.031	0.046	0.660	0.014	0.031	0.431	0.012	0.033
Benzo(b) fluoranthene	0.114	0.132	0.119	0.095	0.158	0.137	0.100	0.171	0.146	0.089	0.153	0.129
Benzo(k) fluoranthene	0.031	0.125	0.253	0.094	0.143	0.311	0.025	0.216	0.177	0.017	0.194	0.157
Benzo(a) pyrene	0.186	0.100	0.141	0.117	0.108	0.186	0.220	0.117	0.198	0.213	0.114	0.175
Indo(1,2,3-cd) pyrene	0.135	0.194	0.196	0.125	0.227	0.219	0.028	0.217	0.226	0.016	0.101	0.195
Dibenzo anthracene	0.195	0.189	0.104	0.104	0.310	0.113	0.032	0.320	0.116	0.021	0.302	0.103
Benzo(g,h,i) perylene	0.124	0.119	0.114	0.124	0.135	0.133	0.256	0.152	0.137	0.217	0.136	0.122
Total	1.946	2.033	1.945	1.840	2.290	2.275	2.500	2.279	2.334	2.052	2.174	2.101

C. lancifolius:

The highest mean concentration of total PAHs in this plant was recorded at DS8 (2.530 ng/g dry weight) while the lowest mean concentration (2.106 ng/g dry weight) was recorded at DS6 (Table 4). Signification differences ($p=0.041$) were found among locations.

The highest seasonal mean concentrations (2.490 ng/g dry weight) were detected during summer season while the lowest seasonal mean concentration (2.041 ng/g dry weight) was during winter season (Table 4). The differences among seasons were not significant ($p=0.267$).

E. camaldulensis:

The highest mean concentration of total PAHs in this plant was recorded at DS6 (2.813 ng/g dry weight) while the lowest mean concentration (2.119 ng/g dry weight) was recorded at DS8 (Table 4). Significant differences ($p=0.007$) were found among locations.

The total PAHs seasonal variations were observed in the present study. The highest seasonal mean concentration (2.634 ng/g dry weight) was detected during spring season while the lowest seasonal mean concentration (2.312 ng/g dry weight) was during winter (Table 4). The differences among seasons were not significant ($p=0.161$).

S. vermiculata:

The highest mean concentration of total PAHs in this plant was recorded at DS7 (2.194 ng/g dry weight) while the lowest mean concentration (2.128 ng/g dry weight) was recorded at DS6 (Table 4). The differences among locations were not significant ($p=0.403$).

The seasonal variations of total PAHs were observed in this study. The highest seasonal mean concentration (2.371 ng/g dry weight) was detected during summer season while lowest seasonal mean concentration (1.975 ng/g dry weight) was during winter (Table 4). Significant differences ($p=0.008$) were found among seasons.

Table 4. Spatial and Temporal variations of Polycyclic Aromatic Hydrocarbons concentrations (ng/g dry weight) in plants species.

locations	Winter	Spring	Summer	Autumn	Sp. Mean	± SD
DS6**	2.319	2.962	3.152	2.820	2.813	0.333
DS7**	2.370	2.639	2.770	2.506	2.571	0.223
DS8**	2.247	2.302	1.978	1.952	2.119	0.162
S. Mean**	2.312	2.634	2.633	2.426	-	-

Locations	Winter	Spring	Summer	Autumn	Sp. Mean	±SD
DS6*	1.876	1.944	2.478	2.126	2.106	0.269
DS7 *	1.929	2.283	2.330	2.107	2.162	0.182
DS8*	2.319	2.680	2.664	2.457	2.530	0.173
S. Mean *	2.041	2.302	2.490	2.230	-	-

Locations	Winter	Spring	Summer	Autumn	Sp. Mean	±SD
DS6***	1.946	2.014	2.500	2.052	2.128	0.251
DS7***	2.033	2.290	2.279	2.174	2.194	0.119
DS8***	1.945	2.275	2.334	2.101	2.163	0.176
S.Mean***	1.975	2.193	2.371	2.109	-	-

* *Conocarpus lancifolius* ** *Eucalyptus camaldulensis* *** *Suaeda vermiculata*

Polycyclic Aromatic Hydrocarbons (PAH) Indices in plants:

Fluoranthene/Pyrene Ratio:

The Fluoranthene/Pyrene Ratio ranged from 0.166 at DS7 in *S. vermiculata* in summer to 2.227 in *C. lancifolius* at DS7 in summer (Table 5).

Phenanthrene/Anthracene Ratio:

Phenanthrene/Anthracene ratio ranged from 0.561 at DS6 in *C. lancifolius* in summer to 1.215 at DS7 in *S. vermiculata* in summer (Table 5).

LMW/HMW Ratio:

LMW/HMW ratio ranged from 0.300 at DS7 in *E. camaldulensis* in autumn to 0.760 at DS7 in *C. lancifolius* in winter (Table 5).

Ant/(Ant+Phen) Ratio:

Ant/(Ant+Phen) ratio ranged from 0.441 at DS7 in *E. camaldulensis* during spring to 0.673 at DS7 in *C. lancifolius* during Summer (Table 6).

Benzo (A) Anthracene/Benzo (A) Anthracene+Chrysene Ratio

BaA/(BaA+Chry) ratio ranged from 0.056 at DS6 in *S. vermiculata* in autumn to 0.931 at DS8 in *Eucalyptus camaldulensis* in summer (Table 6).

InP/(InP+BghiP) Ratio:

InP/(InP+BghiP) ratio ranged from 0.068 at DS6 in *S. vermiculata* in autumn to 0.926 at DS7 in *E. camaldulensis* in winter (Table 6).

Table 5. Pollution indices values of PAHs and their origin source descriptions in the plant samples of the present study.

Locations	Seasons	Fl/Py	Description	Phen/Ant	Description	LMW /HMW	Description
DS 6 *	Winter	0.868	Petrogenic	0.730	Pyrogenic	0.615	Pyrogenic
	Spring	0.886	Petrogenic	0.700	Pyrogenic	0.615	Pyrogenic
	Summer	1.047	Pyrogenic	0.561	Pyrogenic	0.430	Pyrogenic
	Autumn	1.047	Pyrogenic	0.589	Pyrogenic	0.475	Pyrogenic
DS7*	Winter	1.347	Pyrogenic	1.073	Pyrogenic	0.760	Pyrogenic
	Spring	2.062	Pyrogenic	1.000	Pyrogenic	0.730	Pyrogenic
	Summer	2.227	Pyrogenic	0.562	Pyrogenic	0.589	Pyrogenic
	Autumn	1.940	Pyrogenic	0.619	Pyrogenic	0.612	Pyrogenic
DS 8 *	Winter	0.767	Petrogenic	0.751	Pyrogenic	0.528	Pyrogenic
	Spring	0.834	Petrogenic	0.651	Pyrogenic	0.498	Pyrogenic
	Summer	0.703	Petrogenic	0.610	Pyrogenic	0.534	Pyrogenic
	Autumn	0.702	Petrogenic	0.610	Pyrogenic	0.483	Pyrogenic
DS 6**	Winter	1.286	Pyrogenic	0.790	Pyrogenic	0.518	Pyrogenic
	Spring	1.241	Pyrogenic	0.797	Pyrogenic	0.454	Pyrogenic
	Summer	1.800	Pyrogenic	0.630	Pyrogenic	0.409	Pyrogenic
	Autumn	1.183	Pyrogenic	0.660	Pyrogenic	0.425	Pyrogenic
DS 7**	Winter	1.010	Pyrogenic	1.084	Pyrogenic	0.480	Pyrogenic
	Spring	0.952	Petrogenic	1.035	Pyrogenic	0.383	Pyrogenic
	Summer	0.936	Petrogenic	1.121	Pyrogenic	0.537	Pyrogenic
	Autumn	0.882	Petrogenic	1.096	Pyrogenic	0.300	Pyrogenic
DS 8**	Winter	1.480	Pyrogenic	0.914	Pyrogenic	0.416	Pyrogenic
	Spring	1.507	Pyrogenic	0.814	Pyrogenic	0.663	Pyrogenic
	Summer	1.531	Pyrogenic	0.847	Pyrogenic	0.514	Pyrogenic
	Autumn	1.608	Pyrogenic	0.934	Pyrogenic	0.700	Pyrogenic
DS 6 ***	Winter	1.122	Pyrogenic	0.943	Pyrogenic	0.595	Pyrogenic
	Spring	1.085	Pyrogenic	0.887	Pyrogenic	0.544	Pyrogenic
	Summer	1.151	Pyrogenic	0.877	Pyrogenic	0.450	Pyrogenic
	Autumn	1.056	Pyrogenic	0.828	Pyrogenic	0.514	Pyrogenic
DS 7***	Winter	0.567	Petrogenic	1.038	Pyrogenic	0.496	Pyrogenic
	Spring	0.572	Petrogenic	1.136	Pyrogenic	0.485	Pyrogenic
	Summer	0.166	Petrogenic	1.215	Pyrogenic	0.557	Pyrogenic
	Autumn	0.868	Petrogenic	1.134	Pyrogenic	0.516	Pyrogenic
DS 8***	Winter	0.437	Petrogenic	0.888	Pyrogenic	0.559	Pyrogenic
	Spring	1.681	Pyrogenic	0.881	Pyrogenic	0.618	Pyrogenic
	Summer	0.355	Petrogenic	0.820	Pyrogenic	0.585	Pyrogenic
	Autumn	0.299	Petrogenic	0.862	Pyrogenic	0.581	Pyrogenic

* *Conocarpus lancifolius* ** *Eucalyptus camaldulensis* *** *Suaeda vermiculata*

Table 6. Another PAHs pollution indices values and their origin source descriptions in the plant samples of the present study.

Locations	Season	Ant/(Ant+ Phen)	Description	BaA/(BaA+ Chry	Description	InP/(InP+ BghiP)	Description
DS 6*	Winter	0.577	Pyrolytic	0.495	Pyrogenic	0.240	Petrogenic or Pyrogenic
	Spring	0.588	Pyrolytic	0.575	Pyrogenic	0.250	Petrogenic or Pyrogenic
	Summer	0.642	Pyrolytic	0.508	Pyrogenic	0.407	Petrogenic or Pyrogenic
	Autumn	0.629	Pyrolytic	0.529	Pyrogenic	0.395	Petrogenic or Pyrogenic
DS 7*	Winter	0.482	Pyrolytic	0.474	Pyrogenic	0.786	Petrogenic
	Spring	0.632	Pyrolytic	0.085	Pyrogenic	0.731	Petrogenic
	Summer	0.673	Pyrolytic	0.070	Petrogenic	0.467	Petrogenic or Pyrogenic
	Autumn	0.617	Pyrolytic	0.237	Petrogenic or Pyrogenic	0.482	Petrogenic or Pyrogenic
DS 8*	Winter	0.570	Pyrolytic	0.341	Petrogenic or Pyrogenic	0.583	Pyrogenic
	Spring	0.605	Pyrolytic	0.334	Petrogenic or Pyrogenic	0.466	Petrogenic or Pyrogenic
	Summer	0.620	Pyrolytic	0.140	Petrogenic	0.472	
	Autumn	0.620	Pyrolytic	0.158	Petrogenic	0.507	Pyrogenic
DS 6**	Winter	0.558	Pyrolytic	0.919	Pyrogenic	0.510	Pyrogenic
	Spring	0.556	Pyrolytic	0.915	Pyrogenic	0.603	Pyrogenic
	Summer	0.613	Pyrolytic	0.779	Pyrogenic	0.612	Pyrogenic
	Autumn	0.622	Pyrolytic	0.747	Pyrogenic	0.592	Pyrogenic
DS 7**	Winter	0.479	Pyrolytic	0.495	Pyrogenic	0.926	Pyrogenic
	Spring	0.441	Pyrolytic	0.476	Pyrogenic	0.921	Pyrogenic
	Summer	0.471	Pyrolytic	0.324	Petrogenic or Pyrogenic	0.895	Pyrogenic
	Autumn	0.477	Pyrolytic	0.248	Petrogenic or Pyrogenic	0.560	Pyrogenic
DS 8**	Winter	0.501	Pyrolytic	0.580	Pyrogenic	0.569	Pyrogenic
	Spring	0.551	Pyrolytic	0.573	Pyrogenic	0.523	Pyrogenic
	Summer	0.541	Pyrolytic	0.931	Pyrogenic	0.540	Pyrogenic
	Autumn	0.517	Pyrolytic	0.464	Pyrogenic	0.509	Pyrogenic
DS 6***	Winter	0.514	Pyrolytic	0.203	Petrogenic or Pyrogenic	0.521	Pyrogenic
	Spring	0.529	Pyrolytic	0.190	Petrogenic	0.626	Pyrogenic
	Summer	0.532	Pyrolytic	0.460	Pyrogenic	0.098	Petrogenic
	Autumn	0.546	Pyrolytic	0.056	Petrogenic	0.068	Petrogenic
DS 7***	Winter	0.490	Pyrolytic	0.489	Pyrogenic	0.619	Pyrogenic
	Spring	0.468	Pyrolytic	0.403	Pyrogenic	0.627	Pyrogenic
	Summer	0.458	Pyrolytic	0.440	Pyrogenic	0.588	Pyrogenic
	Autumn	0.468	Pyrolytic	0.555	Pyrogenic	0.426	
DS 8***	Winter	0.529	Pyrolytic	0.823	Pyrogenic	0.632	Pyrogenic
	Spring	0.531	Pyrolytic	0.722	Pyrogenic	0.622	Pyrogenic
	Summer	0.549	Pyrolytic	0.784	Pyrogenic	0.622	Pyrogenic
	Autumn	0.536	Pyrolytic	0.762	Pyrogenic	0.615	Pyrogenic

* *Conocarpus lancifolius* ** *Eucalyptus camaldulensis* *** *Suaeda vermiculata*

5. Discussion

Plants are the most important components of the ecosystem because they are the main source of energy on land, in marine or in fresh water. Plants accumulate chemical compounds such as hydrocarbons; hence, they are used as bio-indicators to identify environmental changes in the region (USEPA, 2011).

The predominant light PAHs compounds are Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, and Anthracene while the dominant heavy PAHs

compounds are Floranthene, Pyrene, Benzo(a)Pyrene, Benzo(a)anthracene, Benzo(k) flouranthene (Patel *et al.*, 2015).

The highest levels of PAHs compounds in plants were recorded during summer whereas the lowest levels were found during spring or winter. The seasonal variations may be due to the high temperature during the summer season which is considered as a growth period for these plants due to the long period of solar radiation and the abundance of

nutrients as compared with other seasons. This will lead to an increase in the photosynthesis processes and absorption of the PAHs compounds (Jazza, 2015).

There are differences in the concentration of PAHs compounds among the studied plants. These variations may be attributed to the lipid compounds of each plant species, the nature of growth substrate for each plant, the tolerance of each species to the environmental conditions, and the surface area that affects the rate of accumulation of plants (Hassan *et al.*, 2016). To determine the origin of PAHs according to ratios, the results revealed that LMW-PAHs/HMW-PAHs ratio was less than one during all seasons, indicating that the sources of PAHs in these species were pyrogenic. This finding was in agreement with other studies (Vrana *et al.*, 2001; Al-Hejuje, 2014; Sander *et al.*, 2002).

From the presented results, we can conclude that the source of PAHs compounds in the studied plants is a mix of petrogenic and pyrogenic.

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