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Concentrations, Sources and Distribution of Polycyclic Aromatic Hydrocarbon (PAHs) Compounds in Basrah soils, Iraq

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Abstract

Anthropogenic activities cause soil pollution with different serious pollutants, such as polycyclic aromatic hydrocarbon (PAHs) compounds. This study assessed the contamination of PAHs in soil samples collected from 30 sites divided into eight groups (residential areas, oil areas, agricultural areas, roads, petrol stations, power plants, public parks and electrical generators) in Basrah city-Iraq during 2019-2020. The soil characteristics including (moisture, pH, EC and TOC) were measured. Results showed the following ranges (soil moisture (0.03-0.18%),pH (6.90-8.16), EC (2.48-104.80) mS/cm and TOC (9.90-20.50%)). Gas Chromatography (GC) was used to measure PAHs in extracted soil samples. The total PAH range (499.96 - 5864.86) ng/g dry weight (DW). The most dominant percentage of PAHs in (residential areas, oil areas, agricultural areas, roads, petrol stations, power plants, public parks and electrical generators) in dry season were (BghiP 36% , Chy 29% ,BkF 26% , BaP 18% ,BghiP 27% , InP 40% , BbF 19% and BbF 12%) respectively, while in wet season the most dominant PAHs were (Pyr 22% , BbF 16%, BkF 32% , BbF 36% , BkF 38% , Pyr 26% , BbF 43% and Pyr 35%) respectively. According to some calculated ratios, the sources of PAHs in Basrah soil were mixed between petrogenic and pyrogenic origins. The soil is classified from weakly to heavily contaminated with PAHs.

Keywords: Basrah, Gas Chromatography, PAHs, Soil characteristics, Soil classification.

Introduction

In the last three decades, urbanization, industrialization, and agricultural modernization have increased anthropogenic activities that caused environmental pollution [1,2]. Among these pollutants are Polycyclic Aromatic Hydrocarbon (PAHs) compounds [3].

PAHs are the major group of ubiquitous pollutants, nonpolar organic compounds composed of two or more aromatic rings. In general, they are characterized by slow migration, persistence, lipophilicity and water insolubility. Therefore, they tend to accumulate and stay for a long period in soil. With the increasing number of benzene rings, the molecular weight increases, decreasing their volatility and biodegradability but increasing their toxicity [4-6].

Some PAHs have low-molecular-weight (LMW PAHs) with two or three fused benzene rings, and high-molecular-weight (HMW PAHs) with more than three fused benzene rings[7].

PAHs sources are natural or anthropogenic. Natural sources include volcanic eruptions and decaying organic matter. Also, some plants and algae can create PAHs but in small amounts, which is not considered a pollutant sources [7,8].

The major source of PAHs in soils are anthropogenic activities, especially in urban areas. They come from oil and its derivatives and industrial waste [9]. Incomplete combustion of organic substances is the predominant anthropogenic source that comes from vehicles, industrial sources (refineries, factories, power plants, petrol stations and electrical generators), domestic sources (heating and cooking) agricultural sources (pesticides and open burning of straw) and waste incineration[10-12]. The major paths for the entrance of PAHs to the soil are due to dry and wet

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precipitation from the air and adsorb upon the organic matter of soil [13].

The major sink of different pollutants, including PAHs, are the top soil [14]. They cannot be removed or destroyed from materials that contaminate. These compounds impact the soil structure and lead to a lack of organic matter contents[15].

According to US-EPA sixteen PAHs compounds has been identified as priority pollutants, namely: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, , indeno(1,2,3-c,d) pyrene,, dibenzo(a)anthracene, and benzo(g,h,i)perylene [16].

The soil in Basrah Governorate suffers from severe pollution with oil pollutants, especially polycyclic aromatic hydrocarbons (PAHs) in oil sites and neighboring lands. There are few studies on pollution by PAHs in the soil in Basrah city [2, 12, 17, 18, 19] and there is no enough studies illustrating different sources of PAHs in the soil. Therefore, the present study aims to evaluate the levels, sources and distribution of PAHs in the soil from different locations along with Basrah.

Materials and Methods

Study area

Basrah is the third largest province in Iraq in terms of population (2.532 million people) and the sixth-largest in Iraq in terms of area (19,070 km^2). Economically, it is the economic capital that includes the biggest oil fields, such as Rumaila and Sheaibah fields. Iraq exports most of its oil through Basrah ports, so its economy largely depends on the oil industry. It has many ports, factories, petrol stations, electrical generators, power plants as well as road traffic[16].

Soil sampling and preparation

The soil samples were collected from 30 stations in Basrah city including, eight locations (five residential areas, four oil areas, four agricultural areas, five roads, four petrol stations, two power plant, two parks and four areas near electrical generators) as shown in Fig. 1. The soil samples were taken using stainless steel shovels from topsoil at 3-5 random sites in depth range of 0-15 cm in each station and mixed together to represent a composite sample for each station during the dry season (from July to September 2019) and wet season (from December 2019 to March 2020), placed in aluminum foil wraps, then the soil samples were air- dried at room temperature and sieved with 2 mm mesh sieve.

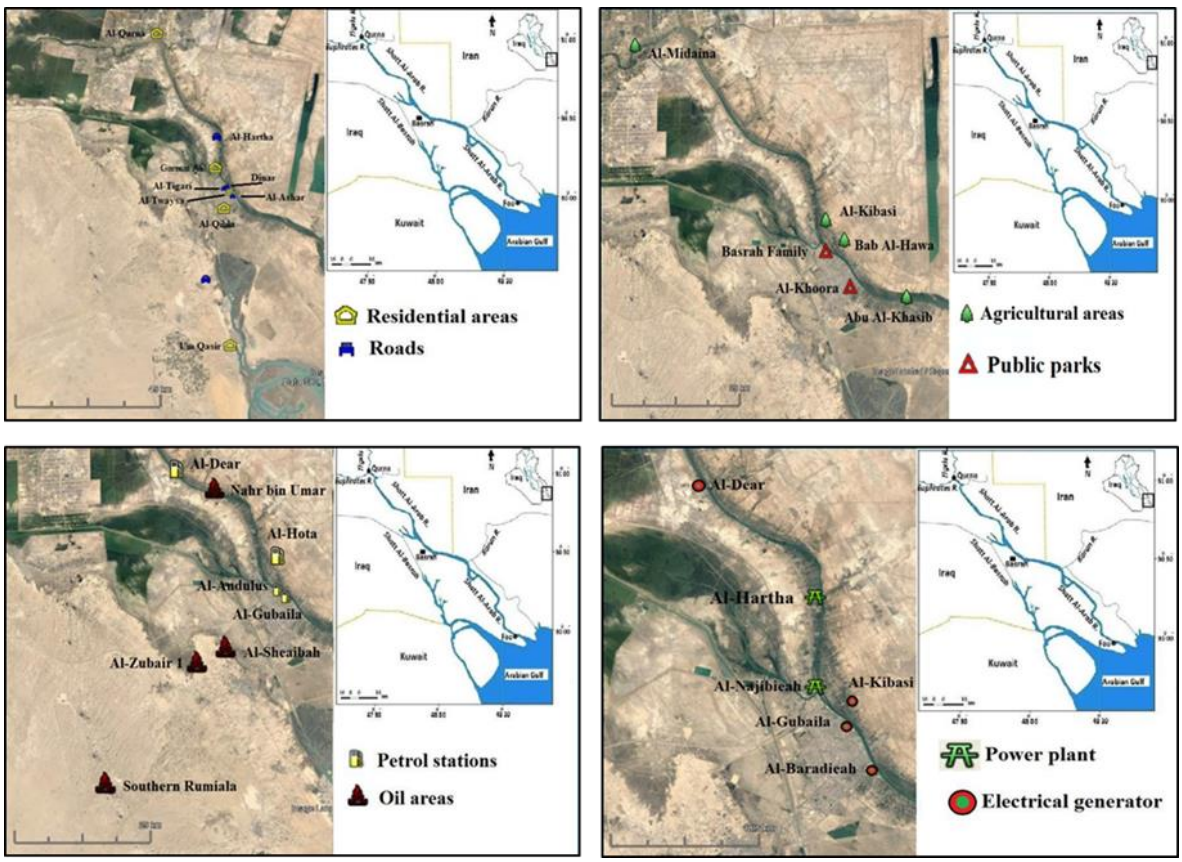

Figure 1. Map of samples collection

Sample analysis

Five grams of soil samples were weighted in the field to measure soil moisture. The weighted soil samples were put into a previously dried and weighted crucibles and then were dried in an oven at 105 °C for 24 hrs. After that, the crucibles were re-weighted to calculate the soil moisture in one gram of soil as a percentage (%) [20]. Dried soil samples were sieved with a 2 mm mesh sieve to prepare soil solution 1:1 to measure pH and Electrical conductivity (EC) according to[20]. Soil solution 1:1 was prepared by mixed 100 gm of soil with 100 ml of deionized water and the mixture was put in a shaker for 30 min. pH measured by using pH meter directly in suspended soil solution, then filtered the soil solution using filter paper (Whatman No.1) to measure EC by using Electrical Conductivity meter

Dried soil samples were grinded finely using a mechanical mortar, sieved through 63 µm , stored in glasses vials until measure the percentage of total organic carbon (TOC%) in soil using the burning method [21] by placed 5 gm of soil in dried and pre-weighted crucible and burned at 550°C for period 48 hrs, then were re-weighted to calculate TOC as a percentage.

Dried and sieved soil were used to measure the PAHs according to [22,23]. Twenty grams of soil were put in thimble and extracted using soxhlet intermittent extraction with mixed organic solvents (100 ml) methanol:benzene (1:1 v/v) for 48 hrs, at temperature below 40°C. The combined extracts were saponification for 2 hrs using (15ml) 4M MeOH(KOH) at the temperature doesn't exceed 40°C, cooled at room temperature. The unsaponification fraction was extracted with n-hexan (50 ml) using a separator funnel. The upper unsaponification fraction with hexane (hydrocarbons) was passed through a glass column with a length of 20 cm. (the bottom packed with glass wool, then about 10 g deactivated silica gel (100-200 mesh), 10 g deactivated alumina (100-200 mesh), and 5g anhydrous sodium sulfate (Na_2SO_4) at the top). The aliphatic fractions were eluted from the column with n-hexane (40 ml), while the aromatics were eluted with benzene (40 ml). The samples were evaporated using a rotary evaporator, stored until detection with a capillary Gas Chromatography to measure PAHs.

To determine the quantities and qualities of PAHs in extracted soil, standard polycyclic aromatic Hydrocarbon were employed to inject in Gas Chromatography (Agilent/ USA 7890A). A carrier gas was Helium was used in Gas Chromatography with flow rate 1 ml /min using flam ionization detector (FID). The temperatures for injector was 300 C° with split mode ratio of 50:1 and detector temperature of 300 C°. Column (model Agilent HP-1 methyl silicon with dimensions (30 m.*320 µm *0.25 µm) was used for aromatic compound separation. Oven initial temperature 120 C° held time 1 min, temperature rate graduated from 6 C°/min to300 C° hold time 11 min. The source of PAHs in soil were investigated according to some calculated ratios as shown in Table 1.

Table 1.The Critical range of Diagnosis ratio of PAHs compounds[2, 12, 24]

Diagnosis ratio	Source of PAHs		
	Pyrogenic	**Petrogenic**	**Either pyrogenic or petrogenic**
LMW/HMW Ratio	**<1**	**>1**	**-**
PHE / ANT	**<10**	**>10**	**-**
FLU / PYR	**>1**	**<1**	**-**
IND/(IND+BENZO)	**>0.5**	**<0.2**	**0.2-0.5**
BENZO A /BENZO A + CHR	**>0.35**	**<0.2**	**0.2-0.35**

Statistical Analysis: Minitab ver.19 software program was used to analyze data through the Analysis of Variance (ANOVA) test to identify the existence of local and seasonal significant variations between the mean concentrations of PAHs in soil samples.

Results and Discussion

The stations of the current study were chosen to cover most sources of hydrocarbons in Basrah city. Some soil characteristics including (moisture, pH, EC and TOC%) were measured in thirty topsoil samples along with Basrah city as shown in Table 2.

Table 2. Soil characteristics in a different location during the dry and wet season in Basrah.

Locations	Moisture%	pH	EC (mS\cm)	TOC %

	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Residential areas	0.05	0.12	7.21	7.49	56.03	52.98	14.64	12.32
Oil areas	0.06	0.08	7.67	7.38	42.35	44.87	15.85	15.35
Agricultural areas	0.16	0.18	7.42	7.10	13.45	25.47	14.15	12.80
Roads	0.03	0.07	7.29	7.48	38.88	49.30	10.76	13.60
Petrol stations	0.04	0.11	7.80	7.88	40.40	41.14	16.05	15.25
Power plants	0.08	0.08	8.08	7.06	104.80	30.75	20.50	16.80
Public parks	0.11	0.12	7.36	6.90	13.46	2.48	16.10	9.90
Electrical generators	0.04	0.12	8.16	7.18	37.37	27.40	16.50	12.80
Min	**0.03**	**0.07**	**7.21**	**6.90**	**13.45**	**2.48**	**10.76**	**9.90**
Max	**0.16**	**0.18**	**8.16**	**7.88**	**104.80**	**52.98**	**20.50**	**16.80**
Mean	**0.07**	**0.11**	**7.62**	**7.31**	**43.34**	**34.30**	**15.57**	**13.60**
SD	**0.04**	**0.04**	**0.36**	**0.31**	**28.76**	**16.40**	**2.72**	**2.16**

The soil moisture levels were ranged from 0.03% on roads in the dry season to 0.18% in agricultural areas in the wet season. The soil moisture in the dry season is less than in the wet season. This is due to increasing the evaporation range in the dry season due to high temperatures. The differences in soil moisture among regions are due to different soil capacities to save water.

The pH levels ranged from 6.90 in public parks in the wet season to 8.16 in electrical generators in the dry season. The results show that pH in most soils was natural, but some region has slight alkaline such as power plant and electrical generators. The differences between soil pH is due to the chemical reaction in soil and the mineral structure of soil [25].

The levels of EC ranged from 2.48 mS/cm in public parks in the wet season to 104.80 mS/cm in power plants in the dry season. Higher EC in most regions is due to the rise of groundwater in these regions [26] and contamination with waste and garbage compared with other regions[25]. TOC levels ranged from 9.90% in public parks in the wet season to 20.50% in power plants in the dry season. The differences in the percentage of TOC % between the locations may be due to variations in organic matter sources[27]**.** The concentration of individual PAHs along Basrah city is shown in Tables 3 and 4. Total PAHs concentrations varied from 499.96 ng\g DW in agricultural areas to 5864.86 ng\g DW in oil areas.

Table 3. The concentration (ng\g DW) of individual PAHs compounds during the dry season.

PAHs compounds	Abbreviation	Residential areas (n=5)	Oil areas (n=4)	Agricultural areas (n=4)	Roads (n=5)	Petrol stations (n=4)	Power plants (n-2)	Public Parks (n=2)	Electrical generators (n=4)
NAPHTHALENE	Nap	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACENAPHTHYLENE	Acy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.21
ACENAPHTHNEN	Ace	0.00	54.09	0.00	0.00	0.00	0.00	0.00	0.00
FLUORENE	Flu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHENANTHRENE	Phe	0.00	83.33	0.00	69.36	2.72	0.00	0.00	173.55
ANTHRACENE	Ant	0.00	118.40	0.00	51.83	26.53	0.00	0.00	110.16
FLUORANTHENE	Fla	86.53	173.65	91.18	275.20	189.41	0.00	88.72	768.76
PYRENE	Pyr	59.49	171.31	8.61	14.98	20.50	0.00	0.00	456.27
BENZO(A)ANTHRAC	BaA	0.00	221.68	0.00	48.47	50.42	0.00	43.22	354.44
CHRYSENE	Chy	48.57	1205.07	107.96	93.53	234.33	729.02	52.60	227.52
BENZO(B)FLUORA	BbF	49.34	326.77	0.00	217.87	101.52	119.71	118.06	516.76
BENZO(K)	BkF	137.72	292.14	129.43	207.90	354.46	39.52	40.17	480.13

FLUORA									
BENZO(A) PYRENE	BaP	162.46	831.15	0.00	269.08	134.21	180.02	46.84	281.16
INDENO(1,2,3-CD)PYRENE	InP	38.74	231.85	110.11	84.46	338.18	801.58	106.21	142.17
BENZO(G,H,I)PERYLEN	BghiP	322.41	431.51	52.67	146.12	538.14	112.25	110.74	660.57
∑ PAHs ($ng.g^{-1}$)		905.26	4140.93	499.96	1478.81	1990.41	1982.09	606.55	4181.71

Table 4. The concentration(ng\g DW) of individual PAHs compounds during the wet season

PAHs compounds	Abbreviation	Residential areas (n=5)	Oil areas (n=4)	Agricultural areas (n=4)	Roads (n=5)	Petrol stations (n=4)	Power plants (n-2)	Public Parks (n=2)	Electrical generators (n=4)
NAPHTHALENE	Nap	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACENAPHTHYLENE	Acy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.80
ACENAPHTHENEN	Ace	0.00	34.06	0.00	41.70	0.00	0.00	0.00	1.06
FLUORENE	Flu	0.00	35.46	0.00	0.00	0.00	0.00	0.00	71.14
PHENANTHRENE	Phe	19.99	212.47	0.00	0.00	0.00	116.22	0.00	392.94
ANTHRACENE	Ant	38.79	160.15	0.00	8.97	0.00	197.77	0.00	378.95
FLUORANTHENE	Fla	48.44	600.70	47.38	177.47	281.19	750.51	0.00	474.45
PYRENE	Pyr	180.52	387.72	0.00	187.78	154.94	1235.17	0.00	1590.80
BENZO(A)ANTHRAC	BaA	6.19	216.35	44.64	49.88	23.92	377.90	0.00	313.05
CHRYSENE	Chy	41.34	385.13	51.66	126.01	41.65	528.96	0.00	330.93
BENZO(B)FLUORA	BbF	151.87	1213.15	84.61	860.18	250.09	420.20	661.08	310.02
BENZO(K)FLUORA	BkF	138.19	671.29	168.35	286.94	931.21	266.24	374.45	209.53
BENZO(A)PYRENE	BaP	166.82	695.50	99.67	462.30	361.87	262.01	347.86	220.84
INDENO(1,2,3-CD)PYRENE	InP	9.42	242.46	0.00	119.85	111.63	245.04	0.00	109.28
BENZO(G,H,I)PERYLEN	BghiP	30.15	1010.43	30.15	85.23	305.54	272.18	157.10	170.65
∑ PAHs ($ng.g^{-1}$)		831.71	5864.86	526.46	2406.32	2462.02	4672.19	1540.49	4579.45

Statistical analysis showed non-significant differences at (P>0.05) in the dry season among locations for most individual PAHs except (BaA) which showed a significant relationship. Still in the wet season, the individual PAHs (Fla, Pyr, BaA and BghiP) showed a significant relationship at (P<0.05) and the remaining compounds showed non-significant relationships.

Statistical analysis showed non-significant differences at (P>0.05) between dry and wet seasons for most individual PAHs in all locations except (BbF and BkF) in oil areas and (Pyr) in roads that showed significant differences.

The individual PAHs found in residential areas in the dry season were (Fla, Chy, BbF, BkF, BaP,InP and BghiP), while the remaining compounds were

not occurred. In the wet season the (Phe and Ant) were found in addition to the (Fla, Chy, BbF, BkF, BaP, InP and BghiP).

In oil areas, all individual PAHs compounds were found in the dry season except (Acy and Flu), which is not found, while all compounds were found in the wet season.

In agricultural areas, six compounds (Fla, Pyr, Chy, BkF, InP and BghiP) were recorded in the dry season, while in the wet season only nine compounds (Phe, Ant, Fla, BaA, Chy, BbF, BkF, BaP and BghiP) were found.

All compounds were recorded in roads in the dry season except (Acy, Ace and Flu), which was not found, but in the wet season (Nap, Acy, Flu and Phe), not found.

In petrol stations, only the (Nap, Acy, Ace and Flu) not occur in the dry season, but in the wet season, the (Phe and Ant) not occur in addition to (Nap, Acy, Ace and Flu).

The compounds in power plants in the dry season were (Chy, BbF, BkF, BaP,InP and BghiP). In the wet season only (Nap, Acy, Ace and Flu) are not found.

In public parks the (Flu, BaA, Chy, BbF, BkF, BaP, InP and BghiP) was recorded in the dry season, but in the wet season only (BbF, BkF, BaP and BghiP) occurred.

All compounds occurred in the soil near the electrical generators except (Nap, Ace and Flu) which has not occurred in the dry season, but in the wet season, all compounds occurred.

The distribution of the percentage of individual PAHs is showen in Fig. 2. The most dominant percentage of PAHs in (residential areas, oil areas, agricultural areas, roads, petrol stations, power plants, public parks and electrical generators) in the dry season were (BghiP 36%, Chy 29%, BkF 26%, BaP 18%, BghiP 27%, InP 40%, BbF 19% and BbF 12%) respectively, while in the wet season the most dominant PAHs were (Pyr 22%, BbF 16%, BkF 32%, BbF 36%, BkF 38%, Pyr 26%, BbF 43% and Pyr 35%) respectively.

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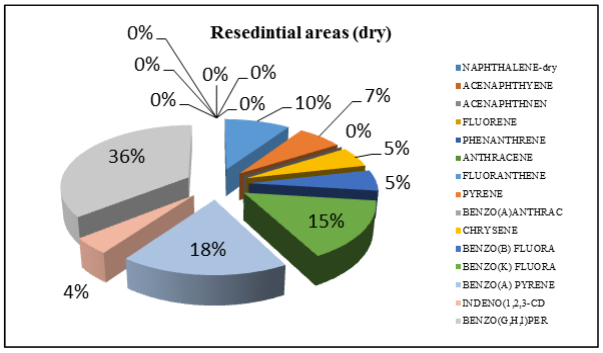

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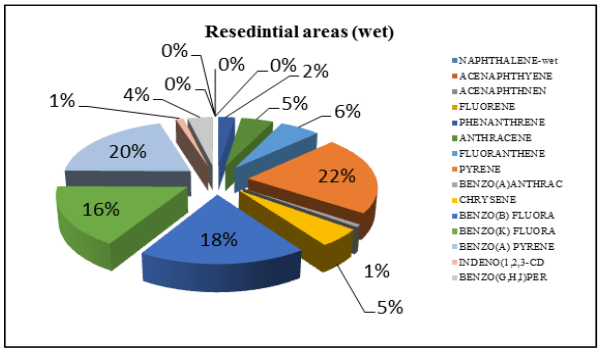

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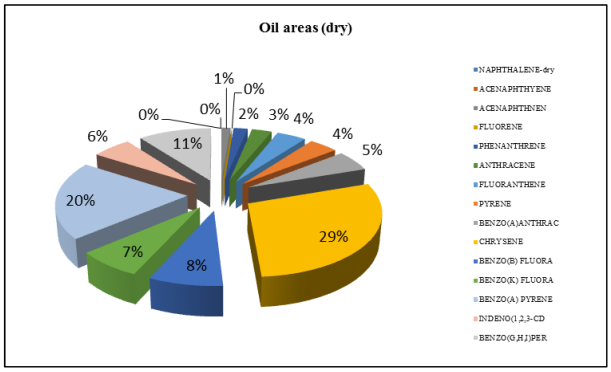

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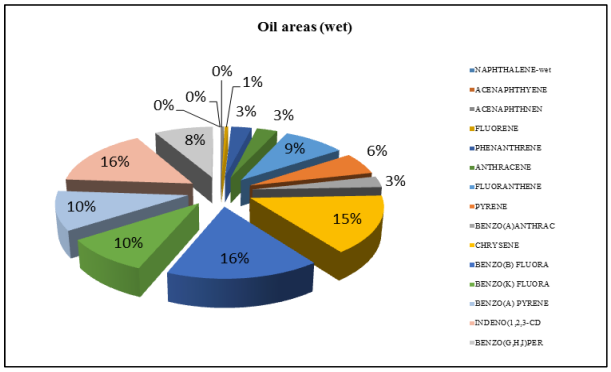

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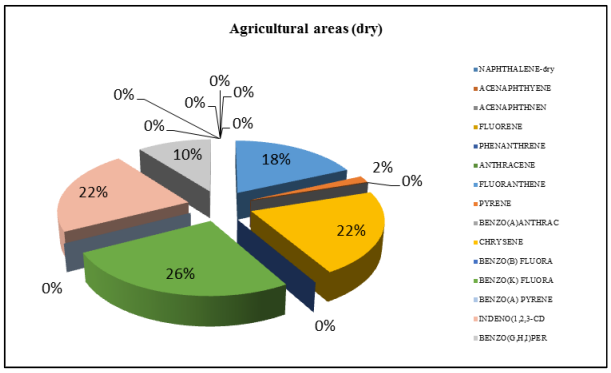

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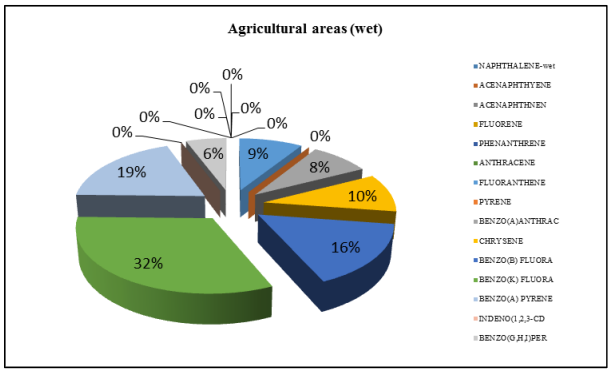

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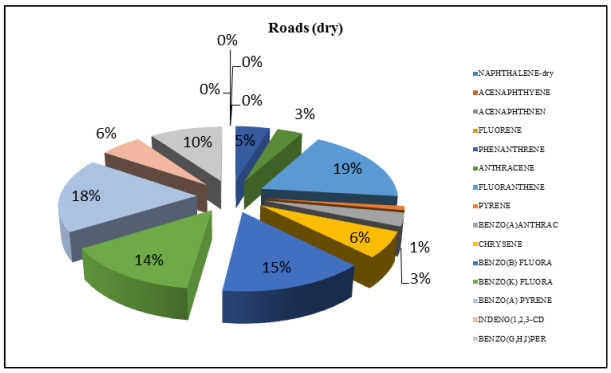

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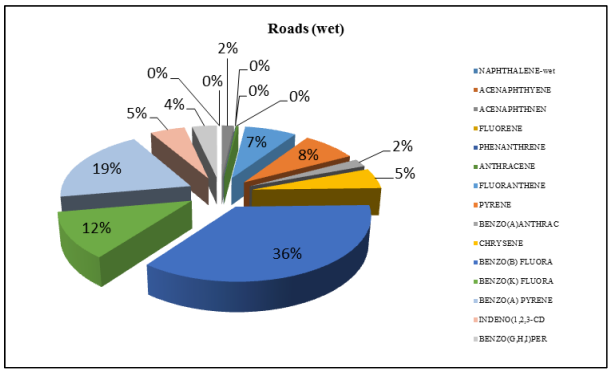

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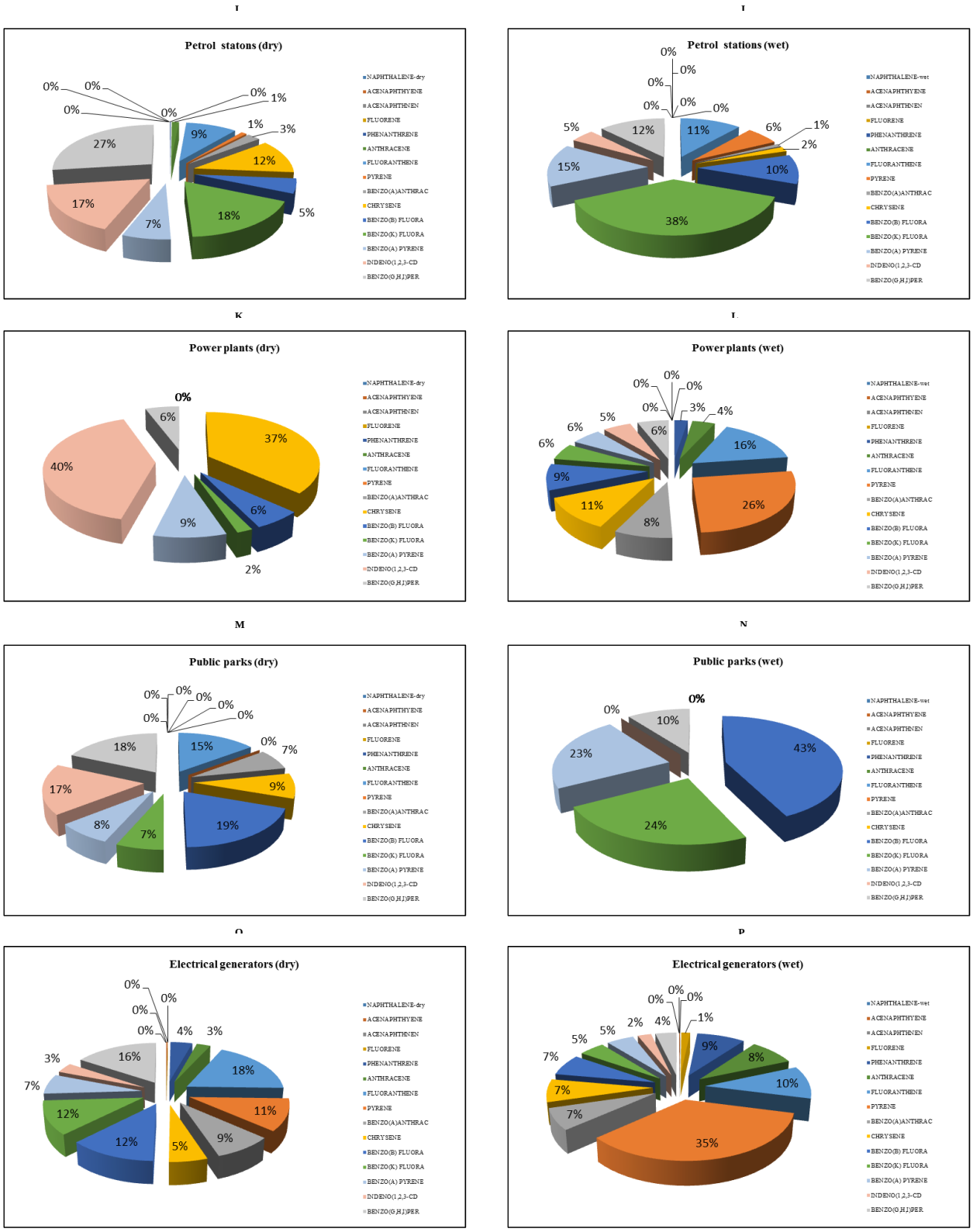

Figure 2. Distribution of individual PAHs percentage in all locations in Basrah city during the dry and wet season

The HMW-PAHs are predominant with high concentrations, but LMW-PAHs are not recorded in most locations. The prevalence of HMW-PAHs in the soil in most locations is due to oil refineries, oil fields, many power plants, roads traffic, vehicles emissions, electrical generators, waste incineration and other activities that depend on fuel combustion at high temperatures that produce large amounts of PAHs and these ubiquitous pollutants accumulated on the soil[4,28]. The rate of biodegradation processes

by microorganisms of LMW- PAHs such as naphthalene and acenaphthene are more rapid than HMW-PAHs such as pyrene, fluoranthene, and benzo(a)pyrene [17,29]. As well as biodegradation LMW- PAHs were evaporated faster than HMW-PAHs due to the high vapor pressure of LMW-PAHs. This was correspondence with other reports[12,30, 31].

Some soils that had low levels of PAHs may be due to microbial flora that degrade these compounds[32]. Residential areas were much polluted with PAHs because of transmission of these compounds by air and deposit onto the soil, in addition to vehicle movement, electrical generators and waste incineration in these areas[1].

In general, agricultural areas and public parks had low levels of PAHs because these areas are far from sources of PAHs. The concentration of total PAHs in the wet season is higher than in the dry season. This is due to the high temperature in the dry season that increases the volatilization and biodegradation rate of PAHs. The degradation rate reaches its highest levels in the environments at the range of temperature 20-30 °C [17]. The classification system of soil pollution according to [33,34] depending on the concentration of total PAHs, the soil was classified as non-contaminated with the total PAHs <200 ng/g, weakly contaminated 200–600 ng/g, moderately contaminated 600–1000 ng/g, and heavily contaminated >1000 ng/g. According to this classification, most soil samples were heavily contaminated by PAHs including (oil areas, roads, petrol stations, power plants and electrical generators), the soil samples from residential areas were moderately contaminated and the soil samples from agricultural areas were weakly contaminated in both dry and wet seasons, except the soil samples from public parks were weakly contaminated in the dry season but they were heavily contaminated in the wet season, as showed in Fig. 3.

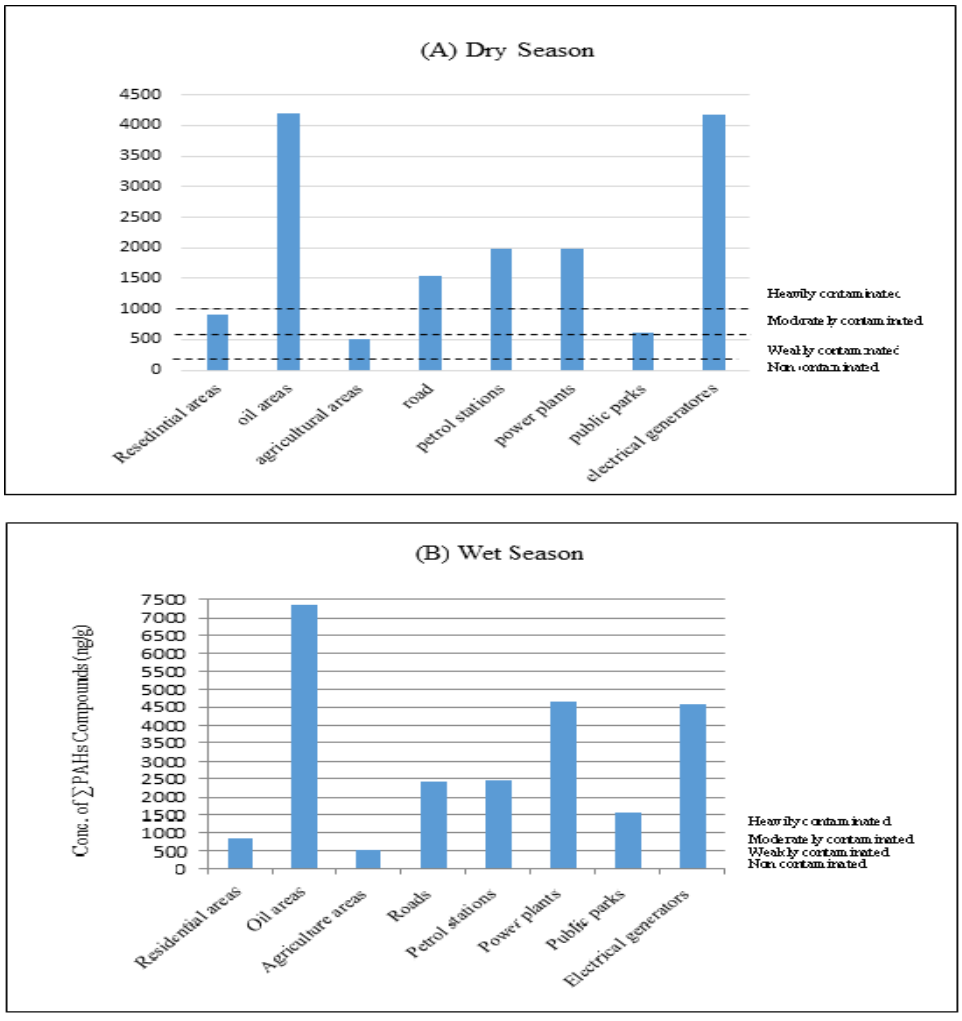

Figure 3. The classification of soil pollution according to levels of PAHs compounds (A) in the dry season (B) in the wet season

The PAH contamination can be related mainly to petrogenic or pyrogenic origins. The occurrence of LMW-PAHs refers to petrogenic origin, while the pyrogenic origin (combustion origin) includes higher concentrations of HMW-PAHs[34]. The diagnosis ratio of PAHs in all study locations in Basrah city is explained in Table 5.

Table 5. Diagnosis ratio of PAHs compounds in study locations

Locations	LMW/HMW Ratio	PHE / ANT	FLU / PYR	IND/(IND+BENZO)	BENZO A /BENZO A + CHR
Residential Areas	0.03	0.07	0.71	0.16	0.02
Sources	pyrogenic	pyrogenic	petrogenic	petrogenic	petrogenic
Oil Areas	0.07	0.62	0.98	0.4	0.29
Sources	pyrogenic	pyrogenic	petrogenic	petrogenic or pyrogenic	Petrogenic or pyrogenic
Agricultural Areas	0	0	0.93	0.18	0.2
Sources	pyrogenic	pyrogenic	petrogenic	petrogenic	petrogenic or pyrogenic
Roads	0.07	0.26	1.94	0.31	0.16
Sources	pyrogenic	pyrogenic	pyrogenic	petrogenic or pyrogenic	petrogenic
Petrol Stations	0.01	0.17	1.46	0.33	0.1
Sources	pyrogenic	pyrogenic	pyrogenic	petrogenic or pyrogenic	petrogenic
Power Plants	0.02	0.15	0.25	0.66	0.35
Sources	pyrogenic	pyrogenic	petrogenic	pyrogenic	petrogenic or pyrogenic
Park	0	0	0.44	0.33	0.11
Sources	pyrogenic	pyrogenic	petrogenic	petrogenic or pyrogenic	petrogenic
Electrical Generators	0.16	0.85	0.91	0.28	0.47
Sources	pyrogenic	pyrogenic	petrogenic	petrogenic or pyrogenic	pyrogenic

The ratio of LMW/HMW in all locations were <1 refers to the pyrogenic origin of PAHs' [24]. Also, the PHE / ANT ratio in all locations were <10 refers to the pyrogenic origin of PAHs [2, 23].

FLU / PYR ratio in roads and petrol stations were >1 refers to the pyrogenic origin of PAHs, but in remaining locations were <1 refers to the petrogenic origin[2]

IND/(IND+BENZO) ratio in residential areas and agricultural areas were <0.2 refers to that PAHs came from the petrogenic origin, in power plants were > 0.5 refers to that PAHs came from the pyrogenic origin, in the remaining locations were between (0.2 – 0.5) refers to PAHs origin were either petrogenic or pyrogenic[2,12,34]

BENZO A /BENZO A + CHR ratio in residential areas, roads, petrol stations and parks were <0.2 refers to that PAHs come from petrogenic origin. While in electrical generators were > 0.35 refers to that PAHs come from the pyrogenic origin, in oil areas, agricultural areas and power plants were between (0.2 – 0.35) refers to that PAHs origin came from either petrogenic or pyrogenic[2,12,24,34]

In this study, these PAHs diagnosis ratio showed that PAHs sources in Basrah soil were mixed between petrogenic and pyrogenic origin. Pyrogenic sources were the dominant sources of PAHs in the soil in the study area that come from vehicle emissions and combustion sources[24] such as the emission from petroleum fields in Basrah. This was in correspondence with other conclusions[2,12,23,27] in Basrah city. By comparing the results of the current study with previous studies in Table 6, we find that the concentration of PAHs in current study is higher than the previous studies of[2,12,17,19,28] but lower than the rest previous studies.

Table 6. Comparison of the current concentrations (ng/g DW) of surface soil PAHs compounds with previous studies in Iraq

Researcher name	Study area	PAHs compounds
Karem *et al*., 2016 [17]	West Qurna-2 Oil Field, Basrah	2.95
Khwedim, 2016 [18]	Rumaila Oil Field, Basrah	12600
Alawi and Azeez, 2016 [35]	Al-Ahdab oil field, Waset	320
Al-Rudaini and Almousawi, 2018 [36]	AL-nahrawan bricks factory, Baghdad	9684.8
Al-Saad *et al*., 2019 [12]	Shatt Al-Arab River Delta, Basrah	41.98
Kadhim, 2019 [2]	West Qurna-1 Oil Field, Basrah	2.49
Al-Rudaini *et al*., 2019 [5]	AL - Zubaidiya Thermal Power Plant, Baghdad	2135.4
Al-Manmi *et al*., 2019 [37]	Sulaymaniyah	2765
Jalal, 2020 [19]	Basrah	17.16
Aoeed *et al*., 2021[28]	Kirkuk	34.59
Current study	Basrah	167.24

In general, Total PAHs concentrations in Basrah city were very high. This is due to oil fields, gasoline combustion in vehicles, power plants, petrol stations and private electrical generators. In addition to tire burning in many roads, near oil companies and near Um Qasser port in Basrah city during demonstrations in October revolution during study periods that put out large quantities of hydrocarbons in soil. All this caused severe pollution with hydrocarbons, which have harmful impacts on humans and the environment.

Conclusions

The soil in Basrah Governorate suffers from severe pollution by polycyclic aromatic hydrocarbons (PAHs). Total PAHs concentrations in the study area were very high compared to previous studies. In general, the agricultural areas and public parks have low levels of PAHs, while oil areas and soil near the electrical generators have high levels of PAHs. The predominant compounds are HMW-PAHs and have higher concentrations, but LMW-PAHs are not recorded in most locations, and their concentrations are very little. The classification system of soil pollution refers to that most soil samples were heavily contaminated by PAHs including, (oil areas, roads, petrol stations, power plants and electrical generators), the soil samples from residential areas are moderately contaminated and the soil samples from agricultural areas are weakly contaminated in both dry and wet seasons, except the soil samples from public parks which are weakly contaminated in the dry season. Still, they are heavily contaminated in the wet season.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Basrah University.

Authors' Contribution Statement

Fadya M. Saleem collected the samples, samples preparation, chemical analysis and final draft writing.
Makia M. Al-Hejuje and Hamid T. Al-Saad laboratory work, data preparation, statistical analysis and final draft editing submission. All authors discussed the results and contributed to the final manuscript.

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تراكيز ومصادر وتوزيع المركبات الهيدروكربونية الأروماتية متعددة الحلقات في ترب البصرة، العراق

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الخلاصة:
تسبب الفعاليات البشرية في تلوث التربة بملوثات خطيرة، منها المركبات الهيدروكربونية الأروماتية متعددة الحلقات. في الدراسة الحالية تم تقييم التلوث بالمركبات الهيدروكربونية الأروماتية المتعددة الحلقات في عينات التربة التي جمعت من ثلاثون موقع موزعة في كافة انحاء البصرة- العراق خلال الفترة 2019-2020 ، وقسمت هذه المواقع الى ثمان مناطق شملت (مناطق سكنية، مناطق نفطية، مناطق زراعية، شوارع عامة، محطات وقود، محطات كهرباء، متنزهات عامة، مولدات كهربائية). قيست خصائص التربة (الرطوبة النسبية، الأس الهيدروجيني، التوصيلية الكهربائية، الكاربون العضوي الكلي). وأظهرت النتائج ان قيم خصائص التربة تراوحت (الرطوبة النسبية (0.03-0.18%) ، الأس الهيدروجيني (6.90-8.16) ، التوصيلية الكهربائية (2.48-104.80) مليسيمنز\سم، الكاربون العضوي الكلي (9.90-20.50%)). استعمل جهاز الكروماتوغرافيا الغازية (GC) في قياس المركبات الهيدروكربونية الأروماتية المتعددة الحلقات في عينات التربة المستخلصة، وأظهرت النتائج ان تركيز المركبات الهيدروكربونية الأروماتية المتعددة الحلقات الكلي تراوح بين(499.96-5864.86) نانوغرام\غم وزن جاف . أكثر المركبات الأروماتية السائدة محسوبة كنسبة مئوية في مناطق الدراسة (مناطق سكنية، مناطق نفطية، مناطق زراعية، شوارع عامة، محطات وقود، محطات كهرباء، متنزهات عامة، مولدات كهربائية) في الفصل الجاف كانت (BghiP 36% , Chy 29% ,BkF 26% , BaP 18% ,BghiP 27% , InP 40% , BbF 19% and BbF 12%) على التوالي، بينما في الفصل الرطب كانت (Pyr 22% , BbF 16%, BkF 32% , BbF 36% , BkF 38% , Pyr 26% , BbF 43% and Pyr 35%) على التوالي.
وبتطبيق مجموعة من الادلة الحسابية لمعرفة مصادر المركبات الأروماتية في الترب المدروسة تبين ان المصدر مشترك ما بين التلوث النفطي وعمليات الحرق. وصنفت التربة بين مستوى ضعيف الى شديد التلوث بالمركبات الهيدروكربونية الأروماتية متعددة الحلقات.

الكلمات المفتاحية: البصرة، كروماتوغرافيا الغاز، المركبات الأروماتية، خصائص التربة، تصنيف التربة.