Using Toxic Equivalent Quotients (TEQs) to Evaluate the Risk of Polycyclic Aromatic Hydrocarbons Compounds in Soil at Basrah Governorate, Iraq

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Abstract: The concentrations of PAHs compounds in this study were estimated in soil of different land uses at Basrah governorate including thirty stations distributed in eight locations (five residential areas, four oil areas, four agricultural areas, five public streets, four petrol stations, two power plants, two public parks and four near private electrical generators). The levels of PAHs compounds mean in all locations ranged from (34.2 - 382.5) ng g⁻¹ dry weight. The means of carcinogenic PAHs compounds in study area varied from (66.4 - 688.8) ng g⁻¹ dry weight and mean of non-carcinogenic PAHs compounds varied from (12.8 - 292.5) ng g⁻¹ dry weight. The carcinogenic PAHs compounds are more dominant than non-carcinogenic PAHs compounds. The human health risk was assessed depending on toxic equivalent quotients (TEQs). The results showed that TEQs ranged from (77.98 - 951.10) ng g⁻¹ dry weight. The TEQs of PAHs in soil samples of oil areas showed the highest level. In general all locations in Basrah governorate were much polluted with PAHs compounds due to urban and industrial development. The present study represents the first study to assess a human health risk due to exposure to PAHs compounds in soil along Basrah governorate.

Keywords: Carcinogenic compounds, Human risk, Iraq, PAHs.

Introduction

Soil is a critical environment because different pollutants come from various human activities, such as agriculture, industry, mining and transports which can pollute the soil with many dangerous pollutants, one of them is polycyclic aromatic hydrocarbon compounds (PAHs) (Wang et al., 2018). Polycyclic aromatic hydrocarbons are specific persistent organic pollutants that stay for long periods in the environment (Ukalska-Jaruga et al., 2020). PAHs compounds composed of two or more aromatic rings (Al-Imarah et al., 2017). With increasing number of benzene rings, the molecular weight increases, hence decreases their volatility and biodegradability, whereas increases their toxicity (Al-Rudaini et al., 2019; Abass et al., 2019). Most of high molecular weight PAHs are carcinogenic and mutagenic, while the lowest molecular weight PAHs are severely toxic but non-carcinogenic to many...
organisms (Laane et al. 2006; Karlsson & Viklander 2008).

Anthropogenic activities are the main source of PAHs that include incomplete combustion of petroleum products, wastes incineration, traffic emissions, house-heating, power plants and other industries (Jiao et al., 2015; Ukalska-Jaruga et al., 2020). Also these compounds come from natural processes such as volcanic activity, decaying organic matter. In addition to plants and algae which can create small amounts of PAHs (Wang et al., 2018).

In general, PAHs occur in an air either bound with suspended particles or as gaseous phase, they may transfer in air for long distances and deposit on water, soil and plants by precipitation processes (Olgun & Doğan, 2020). These ubiquitous pollutants are distributed in environment and transport from soil to groundwater and plants causing human health risk (Cipa et al., 2018).

PAHs compounds are very toxic and characterized for their potential influences of carcinogenicity, mutagenicity and teratogenicity, which are serious to human health due to their tendency to accumulate in the food chain (Cachada et al., 2019). Exposure to these compounds can cause many problems to human including irritation (eyes, skin, and mucous membranes), reduces the function bone marrow, weakness in nervous system and many types of cancers (Moore et al., 2015).

According to U.S. Environmental Protection Agency (US-EPA) sixteen PAHs compounds have been classified as priority pollutants and divided into two groups: carcinogenic and non-carcinogenic to human being. The carcinogenic compounds are seven, including (benzo (a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, dibenzo (a) anthracene, and indeno (1,2,3-c,d) pyrene). The remaining nine compounds are non-carcinogenic, including (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene and benzo (g,h,i) perylene) (Kuppusamy et al., 2020).

The route of human exposure to PAHs compounds are through breathing, ingestion and skin contact (Jiang et al., 2016). Health risk estimation has the biggest effects to discover any potential exposure to PAHs compounds that is associated with harmful impacts either for short or long periods of exposure and the periods following the exposure (Kuppusamy et al., 2020). Therefore the present studies focus on PAHs pollutants.

Because of there is a very little previous studies on PAHs compounds in soil at Basrah governorate, wherefore the aims of this study are to determine PAHs compounds in soil in different location at Basrah governorate and assess the human health risk due to exposure to these hazard compounds.

**Materials and Methods**

**Study area**

The study area is located at Basrah governorate, southern Iraq. Basrah covers an area of (19,070 km²) and has a population of (2.532 million people) (Al-Saad et al., 2019). The studied stations are distributed from north to south at Basrah governorate, divided into thirty stations distributed in eight different land uses that included (five residential areas, four
oil areas, four agricultural areas, five public streets, four petrol stations, two power plants, two public parks and four near private electrical generators) as shown in fig. 1.

Soil sampling and PAHs analysis

The composite soil samples were taken during two seasons the dry season (from July to October 2019) and wet season (from December 2019 to March 2020) from topsoil in depth 0-15 cm using stainless steel shovels. The soil samples taken from 3-5 random sites within each station and mix together as a complex sample and placed in aluminum foil wraps, then the soil samples air-dried at room temperature and sieved through 2 mm mesh sieve.

Dried soil samples were grinded well using a mechanical mortar, sieved through 63 µm and stored in glasses vials until extracted PAHs compounds according to (Goutx & Saliot, 1980). Twenty grams of soil were extracted in soxhlet intermittent extraction using thimble and mixed organic solvents (100 ml) methanol: benzene (1:1 v/v) in rounding flask for 48 hrs. at temperature below 40°C. The saponification process has been done on combined extracts using (15ml) 4M MeOH(KOH) for 2 hrs. at temperature which cannot be exceeded 40°C, then cooled at room temperature. The unsaponification part extracted in a separator funnel with n-hexan (50 ml). The upper unsaponification part (hydrocarbons) with hexane was passed through glass column with length 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 (Na2SO4) at the top). The aliphatic parts
were eluted from the column with n-hexane (40 ml), while the aromatics were eluted with benzene (40 ml). The samples were air dried and stored until detection with a capillary Gas Chromatography and Gas Chromatography-Mass (GC-Mass) to measure PAHs compounds. To estimate the quantities and qualities of PAHs compounds in extracted soil samples, standard polycyclic aromatic compounds were employed to be injected in Gas Chromatography instrument (GC) in Nahr bin Omar laboratories – Basrah Oil Company. GC was made in USA model (Agilent/ USA 7890A). Helium gas used as a carrier gas in Gas Chromatography with flow rate 1 ml/min using flame ionization detector (FID). The injector temperature was 300 °C with split mode ratio 50:1 and detector temperature 300 °C. Column model Agilent HP-1 methyl silicon with dimensions (30 m.*320 μm *0.25 μm) was used for aromatic compounds separation. Oven initial temperature was 120 °C was hold time 1 min, temperature rate graduated from 6 °C min⁻¹ to 300 °C hold time was 11 min.

### Health Risk Assessment

PAHs compounds are characterized by toxicity and carcinogenicity to humans, animals and plants. To determine the carcinogenicity possibility associated with exposure to individual and total PAH compounds, the (TEQs) was calculated depending on the toxic equivalent factor (TEF) of each individual PAH. The (TEQs) was calculated using the following equation (Qiao et al., 2006; Al-Saad et al., 2019; Cao et al., 2019; Li et al., 2020):

\[ \text{TEQs} = \sum (\text{TEFi} \times \text{CPAHi}) \]

Where:

- TEFI: toxic equivalent factor of each PAH compound as showed in table (1) according to (Qiao et al., 2006; Al-Saad et al., 2019).
- CPAHi: concentration of individual PAH compound

### Statistical Analysis

Minitab ver.19 software program was used to analysis data through Analysis Of Variance (ANOVA) test. Also, Relative Least Significant Differences (RLSD) was calculated to identify the existence of significant variations between the mean concentrations of PAHs in soil samples.

### Table (1): Toxic equivalent factor (TEF) of each PAH compound.

<table>
<thead>
<tr>
<th>PAHs compounds</th>
<th>TEF</th>
<th>PAHs compounds</th>
<th>TEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>0.001</td>
<td>Benzo(A)Anthrac</td>
<td>0.1</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>0.001</td>
<td>Chrysene</td>
<td>0.01</td>
</tr>
<tr>
<td>Acenaphthynen</td>
<td>0.001</td>
<td>Benzo(B) Fluora</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluorene</td>
<td>0.001</td>
<td>Benzo(K) Fluora</td>
<td>0.1</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>0.001</td>
<td>Benzo(A) Pyrene</td>
<td>1</td>
</tr>
<tr>
<td>Anthracene</td>
<td>0.01</td>
<td>Indeno(1,2,3-Cd)Pyrene</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>0.001</td>
<td>Benzo(G,H,I)Perylen</td>
<td>0.01</td>
</tr>
<tr>
<td>Pyrene</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table (2): Mean concentration (ng g⁻¹ dry weight) of PAHs compounds classified as carcinogenic and non-carcinogenic in soil at Basrah governorate.
The letters (a, b, c and d) according to RLSD value. The different letters refer to significant differences, while the same letters refer to non-significant differences.

Results & Discussion

Statistical analysis (ANOVA - one way) showed significant differences (P < 0.01) among mean concentrations of total PAHs compounds among locations at Basrah governorate table (2).

Oil area, electrical generator, power plant and petrol stations showed non-significant differences according to Relative Least Significant Differences (RLSD = 237.6, P = 0.05). Also, non-significant differences were found among electrical generator, power plant, petrol stations, roads, public parks residential areas and agricultural areas, while there were significant differences between oil area and the remaining locations.

The lowest mean concentration was 34.2 ng g⁻¹ dry weight in agricultural areas, whereas the highest mean concentration was 382.5 ng g⁻¹ dry weight in oil areas. The sequences of mean PAHs compounds in the studied area followed this order: Oil areas > electrical generator > power plant > petrol stations > roads > public parks > residential areas > agricultural areas.

Anthropogenic activities are the main source of PAHs in soil that includes pyrogenic sources from oil products and vehicle emissions (Liu et al., 2019). The increase of oil products cause to soil structure disorder, Its lead to lack of organic matter contents, soil minerals, soil nutrients, soil fertility, and bad crop yield, It also lead to leaching and erosion of soil (Palese et al., 2003; Nwaichi et al., 2014).

The percentage of individual PAHs compounds at all locations at Basrah governorate, Fig. (2) showed that the most dominant PAHs in (residential areas, oil areas, agricultural areas, roads, petrol station, power plants, public parks and electrical generators) were (BghiP 20%, Chy 20%, BkF 29%, BbF 28%, BkF 29%, Chy 19%, BbF 36 % and Pyr 23%) respectively.

The PAHs compounds are divided into groups depending on number of benzene rings (Cipa et al., 2018), including two benzene rings.
The dominant PAHs compounds in all soil samples were 3–5 rings, this indicates that the PAHs sources originated from industrial activities and heavy traffic emission due to rapid industrial and economic growth (Kim et al., 2019). Results showed that low molecular PAHs (two rings) have low concentrations due to their availability to biodegradability by microorganisms more than high molecular PAHs. Also low molecular PAHs were decreased gradually by dilution due to their high-water solubility (Cipa et al., 2018), while the PAHs compounds with five or more rings have low solubility and volatility, so they are found as solid state and bond to soil particles (Han et al., 2011). Therefore, they are less degradable by microorganisms and this causes that PAHs compounds are more persistent in the environment and stay for long periods (Kim et al., 2019). The present results were in agreement with other reports. (Al-Saad et al., 2017; Al-Saad et al., 2019).

The mean concentration of carcinogenic PAHs compounds in the study area varied from (66.4) at agricultural areas to (688.8) ng g\(^{-1}\) dry weight at oil areas. Statistical analysis (ANOVA one way) showed significant differences (P<0.01) among locations of carcinogenic PAHs compounds.

Statistical analysis (RLSD) showed there were significant differences at (P<0.01) of carcinogenic PAHs compounds between oil areas and the remaining locations. The concentrations of carcinogenic PAHs compounds in the study area followed this order: Oil areas > power plant > electrical generator > petrol stations > roads > public parks > residential areas > agricultural areas.

The mean concentration of non-carcinogenic PAHs compounds varied from (12.8) ng g\(^{-1}\) dry weight at agricultural areas to (292.5) ng g\(^{-1}\) dry weight at electrical generators. Statistical analysis (ANOVA one way) showed there were significant differences at (P<0.05) among locations of non-carcinogenic PAHs compounds.

Statistical analysis (RLSD) showed there were no significant differences at (P<0.05) of non-carcinogenic PAHs compounds among electrical generators, power plants and oil areas and there were no significant differences at (P<0.05) of non-carcinogenic PAHs compounds among power plants, oil areas, agricultural areas, petrol stations, roads, residential areas, public parks; whereas electrical generators had significant differences with the remaining locations.
Fig. (2): The percentage of individual PAHs compounds in all locations at Basrah governorate during the study period.
The concentrations of non-carcinogenic PAHs compounds in the study area followed this order: Electrical generator > oil areas > power plant > petrol stations > roads > residential areas > public parks > agricultural areas. In general, all locations at Basrah governorate were very polluted with PAHs compounds and the concentration of these compounds was very high compared with previous studies except the study of (Khwedim, 2016), table (3). This is due to oil refineries that emit PAHs, as well as combustion of gasoline in vehicles, power plant stations, petrol stations, private electrical generators and wastes incinerations. On the other hand, the burning of tyres in many roads, near oil companies and near Um Qasser port in Basrah governorate during demonstrations in October, 2019 revolution that added large quantities of hydrocarbons to soil.

Table (3): Comparison the current concentrations (ng g⁻¹ dry weight) of surface soil PAHs compounds with previous studies at Basrah governorate.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study area</th>
<th>PAHs compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khwedim, 2016</td>
<td>Rumaila Oil Field</td>
<td>6600 - 4749300</td>
</tr>
<tr>
<td>Al-Saad et al., 2019</td>
<td>Shatt Al-Arab River Delta</td>
<td>17.30 - 72.16</td>
</tr>
<tr>
<td>Kadhim et al., 2019</td>
<td>West Qurna-1 Oil Field</td>
<td>1.335 - 3.592</td>
</tr>
<tr>
<td>Jalal, 2020</td>
<td>Basrah governorate</td>
<td>0.6 - 112.57</td>
</tr>
<tr>
<td>Current study</td>
<td>Basrah governorate</td>
<td>34.2 - 382.5</td>
</tr>
</tbody>
</table>

All these sources cause severe pollution with hydrocarbons which have harmful impacts on humans and environment. The carcinogenic PAHs compounds (BaA, Chy, BbF, BkF, BaP and InP) are more dominant than non-carcinogenic PAHs compounds (Nap, Acy, Ace, Flu, Phe, Ant,Fla, Pyr and BghiP) Fig. 2. The percentage of carcinogenic PAHs in Basrah soils were very high compared with non-carcinogenic PAHs in all locations except the electrical generators in which the percentage of carcinogenic and non-carcinogenic is equal, table (4). This indicates that the carcinogenic PAHs in the study area were the main contributor to total TEQ and this in agreement with Cao et al. (2019).

Health risk assessment

The results of TEQs in present study were ranged from 77.98 ng g⁻¹ dry weight in agricultural areas to 951.10 ng g⁻¹ in oil areas with mean 380.32 ng g⁻¹ dry weight, table (5).
Table (4): The percentage of PAHs compounds as carcinogenic and non-carcinogenic in all locations at Basrah governorate.

<table>
<thead>
<tr>
<th>Location</th>
<th>Non-carcinogenic PAHs</th>
<th>Carcinogenic PAHs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential areas</td>
<td>35 %</td>
<td>65 %</td>
</tr>
<tr>
<td>Oil areas</td>
<td>20 %</td>
<td>80 %</td>
</tr>
<tr>
<td>Agricultural areas</td>
<td>16 %</td>
<td>84 %</td>
</tr>
<tr>
<td>Roads</td>
<td>22 %</td>
<td>78 %</td>
</tr>
<tr>
<td>Petrol stations</td>
<td>26 %</td>
<td>74 %</td>
</tr>
<tr>
<td>Power plant</td>
<td>23 %</td>
<td>77 %</td>
</tr>
<tr>
<td>Public Parks</td>
<td>15 %</td>
<td>85 %</td>
</tr>
<tr>
<td>Electrical generator</td>
<td>50 %</td>
<td>50 %</td>
</tr>
</tbody>
</table>

Table (5): Values of TEQs in all locations at Basrah governorate.

<table>
<thead>
<tr>
<th>Location</th>
<th>TEQs (ng g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential areas</td>
<td>193.81</td>
</tr>
<tr>
<td>Oil areas</td>
<td>951.10</td>
</tr>
<tr>
<td>Agricultural areas</td>
<td>77.98</td>
</tr>
<tr>
<td>Roads</td>
<td>462.44</td>
</tr>
<tr>
<td>Petrol stations</td>
<td>362.17</td>
</tr>
<tr>
<td>Power plant</td>
<td>344.78</td>
</tr>
<tr>
<td>Public parks</td>
<td>266.16</td>
</tr>
<tr>
<td>Electrical generator</td>
<td>384.14</td>
</tr>
<tr>
<td>Mean</td>
<td>380.32</td>
</tr>
<tr>
<td>Min</td>
<td>77.98</td>
</tr>
<tr>
<td>Max</td>
<td>951.10</td>
</tr>
<tr>
<td>SD</td>
<td>260.05</td>
</tr>
</tbody>
</table>

Table (6): Comparison the TEQs (ng g⁻¹) in current study with previous studies in the world.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study area</th>
<th>TEQs (ng g⁻¹ dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jio et al., 2015</td>
<td>Oilfield in China</td>
<td>13.3 - 4397</td>
</tr>
<tr>
<td>Moore et al., 2015</td>
<td>Urban areas in Iran (Isfahan)</td>
<td>1 - 900.53</td>
</tr>
<tr>
<td>Al-Saad et al., 2019</td>
<td>Shatt Al-Arab delta –Basrah</td>
<td>0.523 - 5.834</td>
</tr>
<tr>
<td>Cao et al., 2019</td>
<td>Coking plant in China</td>
<td>39.4 - 559.5</td>
</tr>
<tr>
<td>Cachada et al., 2019</td>
<td>Urban areas in Lisbon (Portugal)</td>
<td>0.59 - 7653</td>
</tr>
<tr>
<td>Li et al., 2020</td>
<td>petrol station in China</td>
<td>6.41 - 72.54</td>
</tr>
<tr>
<td>Current study</td>
<td>Basrah governorate</td>
<td>77.98 - 951.10</td>
</tr>
</tbody>
</table>

The TEQs of PAHs in soil samples of oil areas exceeded the safe level (600 ng g⁻¹) according to the criterion risk of soil for human health protection (Wang et al., 2018), whereas the remain regions the TEQs were lower than 600 ng. g⁻¹. This indicates that oil areas have high levels of carcinogenic dangerous compounds that harm workers and humans in surrounding...
areas. In comparison the TEQs in current study with previous studies in the world (table 6). The concentration of TEQs in study area was very high compared with the study of Al-Saad et al. (2019), Cao et al. (2019) and Li et al. (2020). It was lower than the study of Jio et al. (2015) and Cachada et al. (2019), and it was near to the study of Moore et al. (2015).

**Conclusion**

In this study the levels of PAHs compounds were very high compared with previous studies and the total of carcinogenic PAHs compounds was higher than non-carcinogenic PAHs compounds in all locations except the electrical generators. All studied stations were under the safe level of risk except oil areas were higher than the safe level. In general, Basrah governorate suffers from pollution with PAHs compounds due to increasing combustion processes and vehicle emissions. To confront the dangerous environmental issues, this study could present new views for the management of soil risk of different land uses in Basrah governorate contaminated with PAHs compounds or other organic pollutants.

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**Conflicts of interest**

The authors declare that they have no conflict of interests.

**Contributions of Authors**

F.M.S. : Collected the samples, samples preparation, chemical analysis and final draft writing.

H.T.A. : Laboratory work, data preparation and final draft editing submission.

M.M.A. : Field work sampling, samples preparation and statistical analysis.

All authors discussed the results and contributed to the final manuscript.

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**References:**


https://doi.org/10.1007/978-3-030-51506-5_55

https://doi.org/10.17221/38/2018-SWR


https://doi.org/10.3390/min9030139

https://doi.org/10.3390/ijerph16040670


Goutx, M., & Saliot, A. (1980). Relationship between dissolved and particulate fatty acid and hydrocarbons, chlorophyll (a) and zooplankton biomass in Ville Franche Bay, Mediterranean Sea". Marine Chemistry, 8(4), 299-318.
https://doi.org/10.1016/0304-4203(80)90019-5

https://doi.org/10.1039/C1EM10251F


http://doi.org/10.1016/j.ecoenv.2015.12.037

https://doi.org/10.3390/ijerph120605775

https://jsaer.com/archive/volume-6-issue-7-2019/


https://doi.org/10.1186/s13765-019-0423-7

https://doi.org/10.1007/978-3-030-24035-6

https://doi.org/10.1007/698_5_031

https://doi.org/10.1007/s11356-020-11301-1

http://doi.org/10.1007/s11361-015-4433-6

https://doi.org/10.1007%2Fs10661-014-4037-6

https://doi.org/10.2166/wst.2020.114

http://doi.org/10.1051/agro:2003061

https://doi.org/10.1016/j.envint.2005.04.005

https://doi.org/10.1007/s11366-019-02455-8

https://doi.org/10.3390/ijerph15040607
استخدام حاصل السمية المكافئة (TEQs) لتقييم مخاطر المركبات الهيدروكربونية الأروماتية المتعددة الحلقات في ترب محافظة البصرة، العراق

فادي مشتاق سليم؛ وحادم طالب السعدة؛ وميكية مهلل الحجاج

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كلية علوم البحار، جامعة البصرة، العراق

المستخلص: المركبات الهيدروكربونية العطرية متعددة الحلقات (PAHs) هي ملوثات عضوية معقدة تأتي بشكل رئيسي من الأنشطة البشرية. في هذه الدراسة تم تقدير تركيز مركبات الهيدروكربونات العطرية متعددة الحلقات في التربة من مناطق مختلفة الاستعمالات في محافظة البصرة شملت ثلاثين محطة موزعة على ثمانية مواقع (خمس مناطق سكنية أربع مناطق زراعية، خمسة شوارع عامة، أربع محطات وقود). بلغت نتائج التحليل أن تركيزات المركبات الهيدروكربونية العطرية متعددة الحلقات في التربة تتراوح بين (34.2-382.5) نانوغرام - غرم تراوحت تركيزات المركبات الهيدروكربونية العطرية غير مسرطنة في منطقة دراسة من (66.4-688.8) نانوغرام - غرم وزن جاف. أظهرت معادلات السمية المكافئة TEQs أن المركبات المتعددة الحلقات غير مسرطنة تراجعت بين (12.8-292.5) نانوغرام - غرم تراجعت المركبات مسرطنة بين (77.98-951.10) نانوغرام - غرم. أظهرت النتائج أن تركيزات المركبات الأروماتية المتعددة الحلقات تكون عالية بالقرب من المصادر البشرية مثل الحوادث الكهربائية، اثنتين من الحدائق العامة وأربع مناطق بالقرب من المصادر الصناعية. تراوح مستويات التراكم بين (12.8-292.5) نانوغرام - غرم، و (77.98-951.10) نانوغرام - غرم. كما أن تركيزات المركبات المسرطنة كانت أعلى من تركيزات المركبات غير المسرطنة. تانتها دراسة أول دراسة لتقييم مخاطر mhl للإنسان بسبب التعرض لمركبات الهيدروكربونات العطرية متعددة الحلقات في التربة على طول محافظة البصرة.

الكلمات المفتاحية: المركبات المسرطنة، الخطر على الإنسان، العراق، المركبات الأروماتية.