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Evaluation of Total Petroleum Hydrocarbons in Soils of Basrah City, Iraq

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Abstract

Basrah city suffers from pollution with petroleum hydrocarbons which are toxic to human and to the environment. In the current study the concentrations of total petroleum hydrocarbons (TPHs) were estimated in soils of Basrah city. The study area was included thirty stations distributed in eight locations (five residential areas, four oil areas, four agricultural areas, five roads, four petrol stations, two power plants, two public parks and four areas near private electrical generators) during dry and wet periods (from July 2019 to March 2020). The mean concentrations of TPHs during the study period in all locations were ranged from 8.00 µg/g dw (dry weight) in agricultural areas to 265.11 µg/g dw in roads. The mean concentrations of TPHs in the dry period were ranged from 6.13 to 189.92 µg/g dw, while in the wet period were ranged from 9.87 to 340.29 µg/g dw. It was concluded that oil refineries are the main cause, in addition to other sources of hydrocarbons in soil pollution with petroleum hydrocarbons in Basrah city.

Keywords: TPHs, soil, pollution, basrah, Iraq

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Introduction

Petroleum hydrocarbon contamination poses a significant environmental challenge, particularly in areas surrounding oil refineries and fuel stations (Al-Ali *et al.*, 2016). These hazardous compounds originate from both anthropogenic sources like transportation, urban development, and industrial activities (Banan *et al.*, 2018; Jaruga *et al.*, 2020), as well as natural sources such as volcanic eruptions, forest fires, and decaying organic matter. When accumulated in urban and suburban soils, hydrocarbons can infiltrate the environment through precipitation runoff, volatilize into the air, and be absorbed by plant roots, indirectly polluting water, air, and food sources (Zeng *et al.*, 2009; Bortey-Sam *et al.*, 2014).

Hydrocarbons are defined as chemical compounds consisting solely of carbon and hydrogen atoms (Elkelawy and Eldin, 2018). Petroleum hydrocarbons are mainly composed of two classes: aliphatic hydrocarbons (AHs) and polycyclic aromatic hydrocarbons (PAHs) that form the most of petroleum hydrocarbons (Benlahcen *et al.*, 1997; Resen *et al.*, 2024). Aliphatic hydrocarbons (n-alkanes) show risks to human health and commonly attract the attention of scientific researchers (Cipa *et al.*, 2018) but generally they are less hazard than polycyclic aromatic hydrocarbons (PAHs) compounds that characterized by toxicity and carcinogencity (Fagbote and Olanipekun, 2013).

The primary sources of soil hydrocarbon contamination stem from accidental spills, human activities releasing pollutants, and natural processes (Bardi *et al*., 2000; Agarwal, 2009).

Hydrocarbons have become a global issue in urban and sub urban cities because of their abundance, persistence, toxicity (they are listed as dangerous substances), harmful impacts on organisms and human health, and long-lasting air transportation (Ukalaska & Smreczak, 2020). The majority of human-caused environmental problems stem from the production of hydrocarbon pollutants; over 60% of the world's energy needs are met by oil and natural gas; as modern civilization has advanced over the previous ten years, pressure on energy sources has increased (Ahmed & Fakhruddin, 2018).

Crude oil pollution disrupts soil structure, depleting organic matter, minerals, nutrients, and fertility, while increasing erosion and leaching (Palese *et al*., 2003; Nwaichi *et al*., 2014). Exposure poses direct health risks through inhalation of volatile compounds and dermal contact, as well as indirect risks via ingestion of contaminated food and water (Kuppusamy *et al*., 2020).

The city of Basrah suffers from severe hydrocarbon pollution due to the presence of numerous oil fields, drilling operations, refineries, and associated emissions and spills. In addition to direct soil contamination, pollutants are introduced through leaching from water sources and precipitation from air. Yearly, tons of residues from gasoline combustion by vehicles, power plants, fuel stations, and private generators exacerbate the hydrocarbon burden. These combined sources have resulted in harmful levels of pollution with potential impacts on human health and the environment. This study aims to evaluate the concentrations of total petroleum hydrocarbons (TPHs) in soil samples collected from various regions throughout Basrah.

Materials and Methods

Study area

Basrah is the third largest city in Iraq by population (2.532 million people) and the sixth largest by area (19,070 km^2). It serves as the economic capital, housing Iraq's biggest oil fields including Al-Rumaila and Al-Shuaiba. With its many ports, industries, location on the fertile Mesopotamian plains, and tourist attractions, Basrah is a key agricultural and commercial center (Al-Saad *et al*., 2019; Saleem *et al*., 2022).

This study examined soil samples from 30 stations distributed from north to south across Basrah city, spanning eight location types: five residential areas, four oil fields, four agricultural areas, five major roadways, four gas stations, two power plants, two public parks, and four sites near private generators (Figure 1). These locations were selected to provide representative data on hydrocarbon contamination levels from various potential sources impacting different land use types within the city.

By analyzing soil samples across this diverse range of areas in Basrah, the study aims to comprehensively evaluate the extent and distribution patterns of total petroleum hydrocarbon (TPH) pollution. This data will shed light on the scale of the contamination issue and help identify priority regions and contributing sources to be addressed through future remediation and regulation efforts.

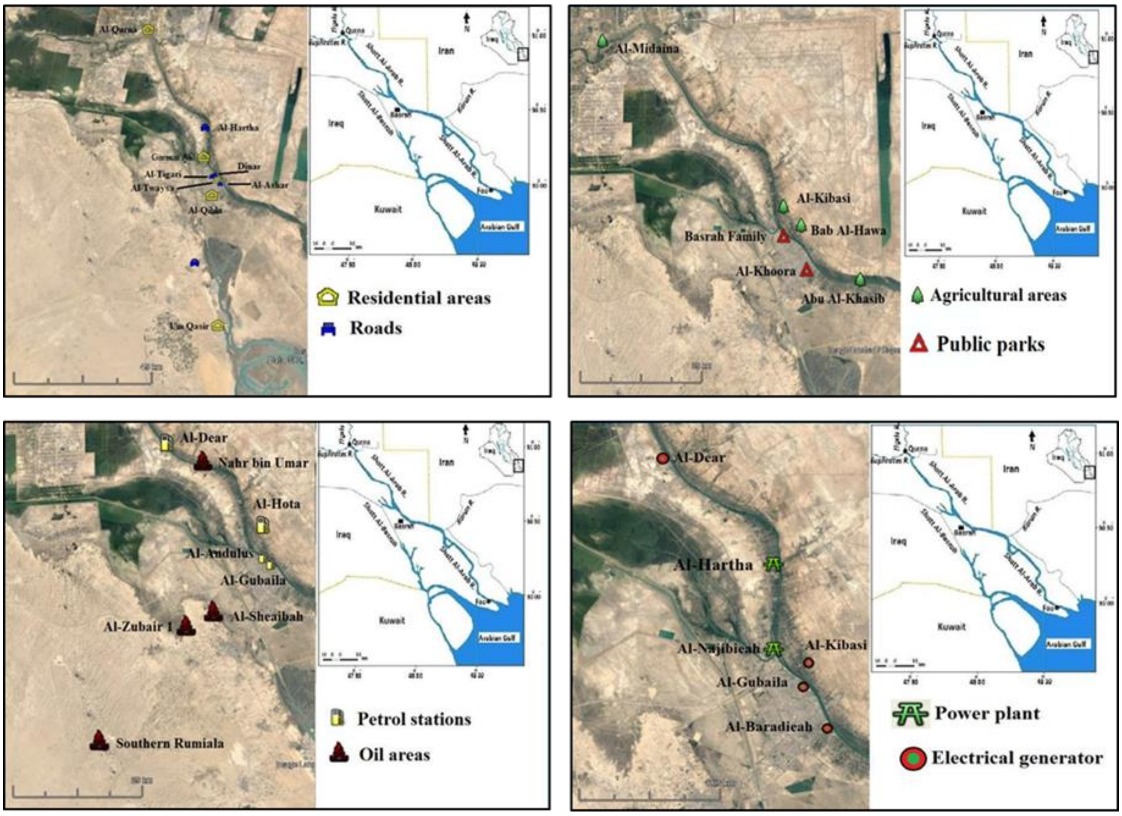

Figure 1: Maps of the study areas.

Soil sampling analysis

Soil samples were collected from the topsoil (0-15 cm depth) using stainless steel shovels during two periods - the dry period (July-September 2019) and the wet period (December 2019-March 2020). At each station, 3-5 random subsamples were obtained and combined into a composite sample, which was wrapped in aluminum foil, air-dried at room temperature, and sieved through a 2 mm mesh sieve.

The dried soil samples underwent further processing by grinding them into a fine powder using a mechanical mortar and sieving through a 63 µm mesh. The processed samples were stored in glass containers until hydrocarbon analysis following the method of Goutx and Saliot (1980). For each sample, 20 g was extracted via Soxhlet extraction for 48 hours using a 1:1 methanol: benzene solvent mixture (100 mL total) maintained < 40°C. The combined extracts underwent saponification for 2 hours with 15 mL of 4M methanolic KOH solution at < 40°C, then cooled to room temperature.

Hydrocarbon compounds were isolated by liquid-liquid extraction into 50 mL n-hexane using a separatory funnel. The unsaponifiable hexane fraction, containing the hydrocarbons, was passed through a 20 cm glass column packed with glass wool at the bottom, followed by 10 g deactivated silica gel (100-200 mesh), 10 g deactivated alumina (100-200 mesh), and 5 g anhydrous sodium sulfate at the top. The aliphatic hydrocarbon fraction was eluted from the column using 40 mL n-hexane, while the aromatic fraction was eluted using 40 mL benzene. Each fraction was then evaporated using a rotary evaporator and stored for subsequent total petroleum hydrocarbon (TPH) quantification via spectrofluorometry.

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 TPHs in soil samples.

Results

The concentrations of total petroleum hydrocarbons (TPHs) in soil samples from the various stations across Basrah city during the dry and wet periods are presented in Figures 2 and 3, respectively.
During the dry period, TPH levels in residential areas ranged from 7.42 µg/g dry weight (dw) at Um Qasir to 82.92 µg/g dw at Al-Twaysa. The oil field sites exhibited higher contamination, with values between 73.06 µg/g dw at Al-Shiaaba and 277.07 µg/g dw at the Southern Rumaila field. Agricultural soils had comparatively lower TPH concentrations from 3.19 µg/g dw in Al-Kibasi to 11.33 µg/g dw in Abu Al-Kasib.
Major roadways showed significant hydrocarbon accumulation, ranging from 103.78 µg/g dw along Dinar Street to 363.58 µg/g dw on Kour Al-Zubair street. Gas stations varied from 10.09 µg/g dw at Al-Hota to 225.11 µg/g dw at Al-Gubaila. Power plant sites contained 29.73 µg/g dw in Al-Hartha to 138.80 µg/g dw in Al-Najibia of TPHs.
Public parks were less contaminated, with 13.30 µg/g dw at Basrah Family and 20.93 µg/g dw at Al-Khoorah. Areas surrounding private electrical generators ranged from 8.25 µg/g dw at Al-Kibasi to 137.85 µg/g dw at Al-Baradieah.
The highest TPH levels correlated with proximal industrial sources like oil fields, high-traffic roadways, and gas stations. Residential neighborhoods, parks, and agricultural areas exhibited comparatively lower soil contamination during the dry period.

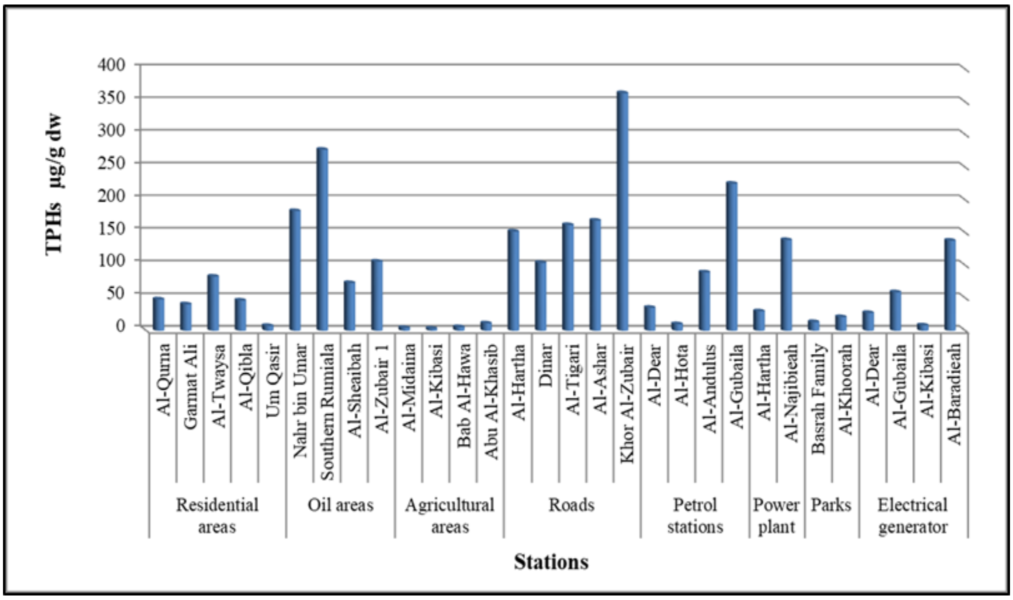

Figure 2: Soil TPH concentrations (µg/g dw) in soil of the studied stations during the dry period.

TPH concentrations in wet period exhibited an overall increase across most locations compared to the dry period (Figure 3). In residential areas, values of TPHs ranged from 10.28 µg/g dw at Al-Qibla to 205.85 µg/g dw at the highly contaminated site of Al-Qurna. In oil field soils values of TPHs ranged from 17.92 µg/g dw in Al-Shiaaba, to 283.18 µg/g dw

in the Southern Rumaila field that remaining the most polluted.
Agricultural soils saw a modest rise to TPHs from 6.70 µg/g dw in Al-Kibasi to 15.93 µg/g dw in Abu Al-Kasib. However, major roadways displayed a stark increase, with TPH levels reaching 82.14 µg/g dw along Al-Ashar street and an alarmingly high 1266.60 µg/g dw on Dinar Street.
The TPHs in gas station sites ranged from 9.51 µg/g dw at Al-Dear to 25.35 µg/g dw at Al-Andulus. Power plant TPH levels ranged from 41.34 µg/g dw in Al-Hartha to 83.18 µg/g dw in Al-Najibia. In public parks TPH levels ranged from 34.12 µg/g dw in Al-Khoorah to 108.43 µg/g dw in Basrah Family Park.
Areas around private generators contained 4.33 µg/g dw (Al-Kibasi) to 154.70 µg/g dw (Al-Gubaila).
The data indicates higher TPHs mobility and accumulation in the wet period, with roadways like Dinar Street showing over a 3-fold increase, likely due to precipitation runoff redistributing pollutants. Residential neighborhoods and areas impacted by hydrocarbon sources also displayed elevated contamination in wet period compared to drier conditions.

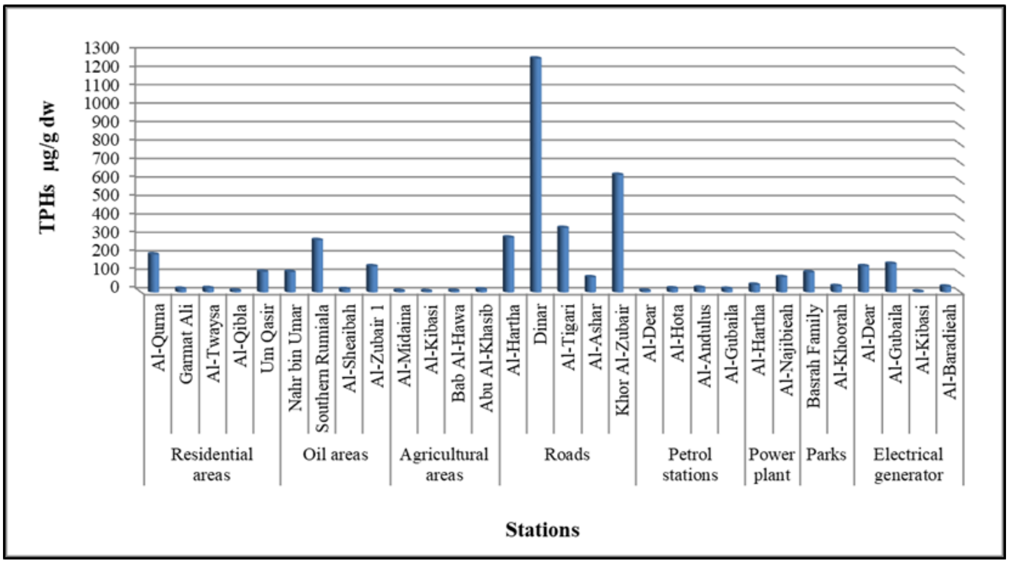

Figure 3: Soil TPH concentrations (µg /g dw) in soil of the studied stations during the wet period.

The annual mean concentrations of Total Petroleum Hydrocarbons (TPHs) during the study period varied across locations, as shown in Table 1. The agricultural areas exhibited the lowest TPHs concentration at 8.00 µg/g dw, while the highest concentration of 265.11 µg/g dw was recorded in road samples. During the dry period, the mean TPHs concentration ranged from 6.13 to 189.92 µg/g dw, whereas in the wet period, the range was higher, spanning 9.87 to 340.29 µg/g dw

Table 1: The annual concentrations of TPHs (µg/g dw) during the study period in all locations.

Locations	TPHs (µg/g dw)		Annual mean of TPHs (µg/g dw)
	Dry period	Wet period	
Residential areas	45.02	74.22	59.62
Oil areas	159.81	138.42	149.12
Agricultural areas	6.13	9.87	8.00
Roads	189.92	340.29	265.11
Petrol stations	89.93	19.07	54.50
Power plants	84.26	62.26	73.26
Public parks	17.11	71.28	44.20
Electrical generators	58.06	83.05	70.56
Min	6.13	9.87	8.00
Max	189.92	340.29	265.11
Mean	81.28	99.81	90.54
±SD	65.11	104.94	80.90

Statistical analysis employing one-way analysis of variance (ANOVA) revealed significant differences ($p < 0.05$) in TPH concentrations among the studied locations during the dry period. However, the differences were found to be non-significant ($p > 0.05$) during the wet period. Furthermore, the comparison of TPH levels between the dry and wet periods across all locations did not yield significant differences ($p > 0.05$).

Discussion

Total petroleum hydrocarbons (TPHs) are organic compounds considered toxic environmental pollutants (Al-Halfy *et al*., 2021). In the current study, higher TPH values were recorded in road and oil areas, while lower values were observed in agricultural areas. Soil contamination with TPHs can result from industrial, agricultural, and domestic activities (Al-Ali *et al*., 2016). The elevated TPH levels in the studied locations can be attributed to the discharge of petroleum wastes from refined oils, gas production plants, natural gas flares, transportation, power plants, private electrical generators, vehicle emissions, and crude oil extraction and production in oilfields (Al-Saad *et al*., 2015; Karem, 2016; Kahdim, 2019). The lower TPH concentrations in agricultural areas may be due to their distance from petroleum sources or the uptake of these compounds by plants (Košnář *et al*., 2018). Studies emphasize that the greatest future risk is related to the increase of petroleum hydrocarbon pollution, which may appear in soils near expressways (Badowska and Bandzierz, 2019).

Differences in TPH values were observed between the dry and wet periods. In some stations, the values were higher during the dry period, while in others, the wet period exhibited higher values. A significant negative correlation was found between TPHs and soil moisture in both the dry period (r = -0.524, p < 0.01) and wet period (r = -0.409, p < 0.05). The results for some stations align with previous studies by Douabul *et al*. (2012), Karem (2016), Al-Hassen (2011), and Kahdim (2019), who found higher TPH concentrations in winter than in summer. However, the results for other stations contradict these previous findings (Table 2). This discrepancy may be due to the hot and dusty climate in summer, leading to increased atmospheric deposition of compounds onto the soil (Al-Rudaini *et al*., 2019), or the increased usage of private electrical generators, which can add substantial quantities of TPHs to the soil. The exceedingly high TPHs value observed in road samples during the wet period may be attributed to tire burning in many roads near oil companies and the Um Qasir port in Basrah city during the October revolution demonstrations, which released large quantities of hydrocarbons into the soil during the study period.

Table 2: Comparing the soil TPHs (µg/g dw) in the current study with previous studies.

Researcher name	Study area	TPHs µg/g dw
Al-Hassen (2011),	Basrah city	8.33 – 16.83
Douabul *et al*., (2012)	Basrah city	13.0 - 38.8
Al-Ali *et al*, (2016)	Basrah city	2.2 - 75.05
Karem (2016)	West Qurna-2 Oil Field	16.66 - 37.37
Kadhim (2019)	West Qurna-1 Oil Field	9.52 - 31.04
Al-Halfy *et al*., 2021	Rumaila Oil Field	0.5 – 93.95
Current study	Basrah city	8.00 – 265.11

Conclusions

Soil analysis in Basrah city revealed the highest TPH concentrations in road and oil areas, and the lowest levels in agricultural areas. TPH levels were generally higher than previous studies in the region. This increase can be attributed to continuous discharge of petroleum wastes from oil refineries, gas plants, transportation, power generation, vehicle emissions, and crude oil production activities. Stringent mitigation measures are needed to prevent further soil contamination from these sources in Basrah city.

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تقييم الهيدروكربونات النفطية الكلية في ترب مدينة البصرة، العراق

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المستخلص
تعاني مدينة البصرة من التلوث بالمواد الهيدروكربونية النفطية السامة للإنسان والبيئة. في الدراسة الحالية تم تقدير تراكيز الهيدروكربونات النفطية الكلية (TPHs) في ترب مدينة البصرة. شملت منطقة الدراسة ثلاثين محطة موزعة على ثمانية مواقع (خمس مناطق سكنية وأربع مناطق نفطية وأربع مناطق زراعية وخمس طرق عامة وأربع محطات بنزين ومحطتين لتوليد الطاقة الكهربائية وحديقتين عامتين وأربع مناطق قريبة من المولدات الكهربائية الأهلية) أثناء فترتي الجفاف والرطوبة (من يوليو 2019 إلى مارس 2020). تراوح معدل تراكيز الهيدروكربونات النفطية الكلية خلال فترة الدراسة في جميع المواقع من 8.00 ميكغم/غم وزن تربة جاف في المناطق الزراعية إلى 265.11 ميكغم/غم وزن تربة جاف في الطرق العامة. وتراوح معدل تراكيز الهيدروكربونات النفطية الكلية في فترة الجفاف من 6.13 إلى 189.92 ميكغم/غم وزن تربة جاف ، بينما تراوح في الفترة الرطبة من 9.87 إلى 340.29 ميكغم/غم وزن تربة جاف. استنتجت الدراسة الحالية أن مصافي النفط بالإضافة إلى مصادر أخرى للهيدروكربونات هي السبب الرئيسي في تلوث التربة بالهيدروكربونات النفطية في مدينة البصرة.

كلمات مفتاحية :الهيدروكربونات الكلية النفطية، التربة، التلوث، البصرة، العراق.