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Anthropogenic and Sediment Controls on TPH in Tigris Sediments

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Abstract. **General Background:** Petroleum hydrocarbons are persistent aquatic contaminants that accumulate in sediments and serve as records of environmental pollution. **Specific Background:** The Tigris River in Maysan Governorate faces increasing hydrocarbon inputs associated with urbanization, industrial discharge, and riverine processes. **Knowledge Gap:** Limited integrated assessments have examined the vertical and spatial distribution of Total Petroleum Hydrocarbons (TPHs) alongside Total Organic Carbon (TOC) and sediment grain size within core sediments of this river system. **Aim:** This study investigates the distribution patterns of TPHs and their relationships with TOC and sediment texture across seven stations (0–50 cm depth). **Results:** TPH concentrations ranged from 4.49 to 114.13 µg/g, with the highest values at Al-Amara and Ali Al-Sharqi linked to anthropogenic sources. Fine-grained sediments (silt and clay >70%) corresponded with higher TOC (1.66–10.73%), while correlation analysis showed weak association between TPH and TOC but strong relationships between TOC and fine fractions. **Novelty:** The study integrates vertical profiling and sedimentological controls to distinguish anthropogenic inputs from natural retention mechanisms. **Implications:** Findings support targeted monitoring and sediment management strategies in hydrocarbon-affected river systems.

Highlights:

- Anthropogenic proximity governs peak hydrocarbon accumulation.
- Fine-grained sediments regulate organic matter retention.
- Vertical cores document historical contamination layers.

Keywords: Total Petroleum Hydrocarbons, Tigris River, Sediment Core, Total Organic Carbon, Grain Size

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Introduction

Petroleum hydrocarbons are an important class of contaminant which are widely distributed in aquatic environments and are the result of both natural processes (e.g. oil seeps) and anthropogenic processes (e.g. petroleum production, transportation and industrial effluent). [1] [2], [3], [4] Once released into the aquatic ecosystem these substances tend to end up into the sediments which are permanent repositories and memory books of pollution. [5], [6], [7].

Therefore, the determination of total petroleum hydrocarbons (TPHs) contained within matrix sediments is critical to the understanding of the extent of petroleum contamination, the sources and the environmental potential of petroleum contamination. [8], [9], [10], [11]. The term TPH refers to the total amount of hydrocarbons that are present in an environmental matrix and that are obtained from petroleum, without any distinction being made as to the constituents of the hydrocarbon. [12], [13].

These substances are made of a complex mixture of aliphatic compounds (n-alkanes and cycloalkanes) and aromatic hydrocarbons which vary in molecular weight and physicochemical properties [14], [2]. The presence of various factors such as the distance from pollution source, hydrodynamic condition, the grain size composition and organic carbon content, has influenced the distribution of TPHs in sedimentary environments. [9], [15], [16], [17]. the fine-grained sediment and organic-rich sediments revealed higher concentrations of TPHs because of its high surface area and high adsorption capacity [2], [18], [19]. Total Organic Carbon (TOC) is the volume of organic material which remains in sediments post-deposition comprised of organic material that has been partially degraded or preserved to varying extents. [20], [21], [22].

The source of TOC is a terrestrial plant, productivity in the water, and human activity. [23]. Higher TOC concentrations are normally correlated with higher ability of retention of petroleum hydrocarbons since organic matter enhances the sportive characteristics of sediments for hydrophobic compound. [24]. there for TOC has been identified to act as a basic parameter that controls the spatial and vertical distribution of petroleum hydrocarbons in aquatic sedimentary settings.

The combined characterization of TPHs and TOC depicted better understanding of the characteristics, sources and fate of organic contaminants. While TOC is representative of overall organic loading from natural processes and anthropogenic sources, TPHs are considered to be a diagnostic indicator of petroleum-related contamination associated with industrial and anthropogenic activities. The combination of the parameters enhances identification of hydrocarbon accumulation zones, identification of the possible pollution source, and estimation of long-term ecological impact of petroleum hydrocarbon on river ecosystems [1], [2], [24], [25], [26], [27].

Because of change in hydrological regimes, rapid urbanization, industrial growth, growing hydrocarbon related activities, in the Tigris River, Maysan Province, southern Iraq, there have been faced serious concerns on the contamination of sediments by hydrocarbons. Since the river is vital to the area in provision of livelihoods and ecosystems [28], [5], [29]. There is need to examine the risk of the hazardous pollutants in the river sediments, such as total petroleum hydrocarbons. Constant monitoring and thorough analysis is essential towards the knowledge of the level of toxicity, determination of the long-term effects and the creation of powerful methods to mitigate and control these to the benefit of the aquatic ecosystems and the health and safety of human beings in the

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Method

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Sampling Sites and Core Collection

The sample cores were taken on the 2 nd of November of 2023 in seven separate locations known as sampling stations that are strategically positioned along the Tigris River in the Maysan Governorate in Southern Iraq as shown in Figure (1). Such stations have been identified selectively to cover upstream, midstream and downstream sectors of the river to capture adequately capture any potential spatial variations in hydrocarbon influx.

PVC coring tubes that had length of 100 cm and a diameter of 6.5 cm were used to carry out the sampling procedure. One corer was inserted in an upright position with each insertion through the sediment-water interface and smoothly driven downward to achieve best penetration of the level of the sedimentary structure and not with damage to the structure. The removal of core sediments was then done gradually to ensure that the natural organization of the sediments was preserved.

As soon as it was retrieved the distal end of Each core was carefully sealed with a rubber stopper, and the proximal aperture closely topped to preserve the level of moisture and reduce the oxidation potential. Each core was then labeling with the station name, date of collection and had an upper orientation and then placed in the refrigerated containers and transfer to the laboratory to be prepared and analyzed.

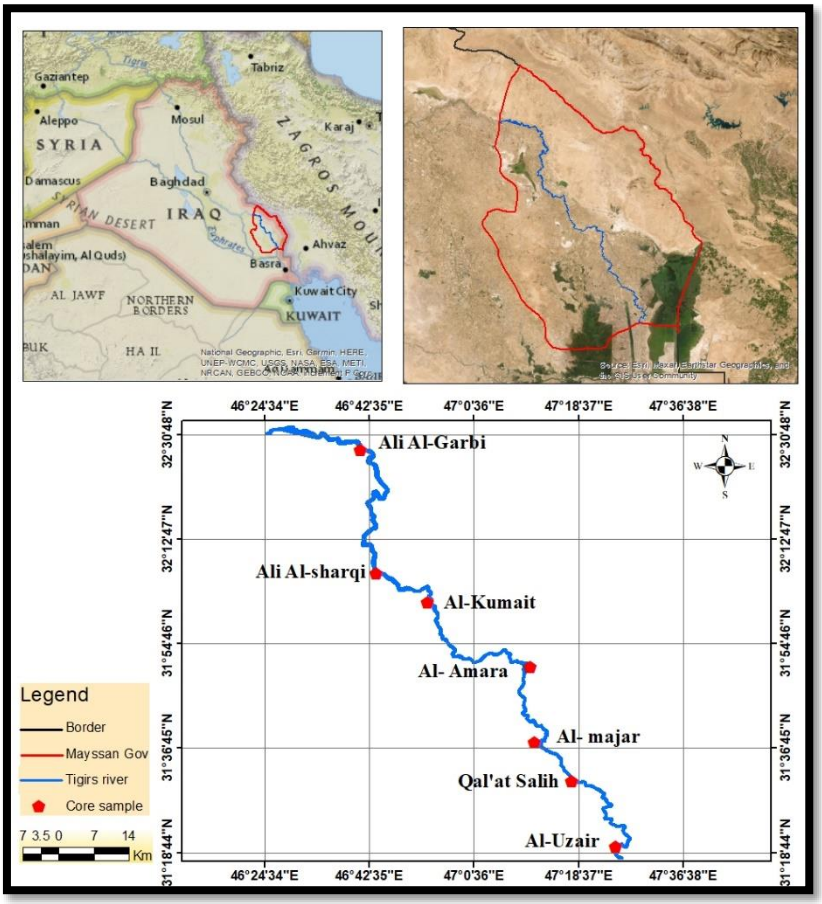

Fig. (1): Location of the study area

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Laboratory Preparation

Each core was removed vertically in the laboratory in depth masses (0-5, 5-10, 10-15 cm, etc.). The samples were allowed to dry because it was in an air-dried condition, disaggregated, and sieved through a (63 um) mesh to eliminate coarse particles and make it homogeneous. The sediment fractions were then dried and kept into clean bottles of glass awaiting chemical analysis.

Determination of Total Petroleum Hydrocarbons (TPHs)

The spectrofluorometric method was employed in the determination of the concentration of TPHs in sediment sample, as mandated by the standard environmental procedure [30].

About (5 g) of each of the dried sediment samples was extracted using a suitable organic solvent like n-hexane or dichloromethane. A filter was used to get rid of any impurities, and the intensity of the fluorescence was recorded using a spectro-fluorometer with an excitation wavelength of (310 nm) and a (360 nm) emission wavelength.

The calibration process was done by the means of the comparison of the measured fluorescence intensity with the calibration curve and the concentrations of the samples were obtained with the help of a series of TPH standard solutions. Findings were given in micrograms per gram of the dry weight (μg/g dw). Triplicate analyses were conducted to provide the reliability of the methodology used in the analytical process and negative samples were used to verify the contamination and the accuracy of instruments.

Determination of Total Organic Carbon (TOC)

The concentration of Total Organic Carbon (TOC) in sediments was identified by the Loss on Ignition (LOI) approach as suggested by [31] and [32]. A (2 g) of dried and sieved (s size 63 um to 48 hours) sediment was heated in a pre-weighed and pre-dried porcelain crucible (550 deg C) 48 hours) in a muffle furnace. The crucible was weighed and cooled down in a desiccator after combustion and then was heated again a number of times until the weight was constant. The calculation of all the TOC percentage was based on the following equation:

$TOC\% = (W1-W2)/W*100$………. (1)

where:

$W1$= weight of crucible + sample before ignition (g)

$W2$= weight of crucible + sample after ignition (g)

W = weight of sample before ignition (g)

All measurements were carried out in duplicate to minimize analytical error and ensure precision.

Grain Size Analysis

The mean grain size of the sediment samples was determined using the pipette method described by [33]. Initially, (20 g) of dried sediment was placed in a beaker, and distilled water was added to facilitate the disaggregation of sediment particles into sand, silt, and clay. The

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suspension was then passed through a 63 µm sieve to separate the sand fraction from the finer materials (silt + clay). The sand fraction was collected in a pre-weighed beaker and dried in an oven for (24 hours) at (105 °C). The remaining suspension containing silt and clay was transferred to a 1000 mL graduated cylinder and washed several times with distilled water to remove dissolved salts until the suspension became clear. Subsequently, (20 mL) of (20%) sodium hexametaphosphate solution was added as a dispersing agent and allowed to stand for (4 hours) and (6 minutes).

A (20 mL) aliquot of the suspension was then withdrawn from a depth of 5 cm using a volumetric pipette and transferred to a pre-weighed beaker. This subsample was dried for (24 hours) at (105 °C) and weighed to determine the clay content of the sediment. According to such measurements, the proportional distribution of sand, silt and clay were determined and employed to classify the sediment texture and determine its impact on the hydrocarbon retention.

Statistical Analysis

Descriptive statistics was used to calculate the range, mean and S.D of the TPH and TOC concentration at the various depths of the stations. To understand more about the factors that control hydrocarbon distribution in the sediments, correlation analysis was conducted to determine which factors have relationships between TPHs, TOC, and grain sizes fractions.

Result and Discussion

Vertical Distribution of Total Organic Carbon (TOC), Total Petroleum Hydrocarbons (TPHs), and Grain Size of Tigris River Sediments

Table (1): Total Petroleum Hydrocarbons (TPHs dw) within core sediment of the study stations.

Station	Depth (cm)	Range (µg/g)	Mean	±SD	SE
Al-Uzair	0–5	25.22–25.24	25.23	0.01	0.005
	5–10	31.51–31.56	31.53	0.02	0.01
	10–15	29.77–29.83	29.80	0.03	0.01
	15–20	13.75–13.78	13.77	0.01	0.005
	20–25	12.41–12.48	12.44	0.03	0.01
	25–30	15.33–15.38	15.36	0.02	0.01
	30–35	17.01–17.05	17.03	0.02	0.01
	35–40	9.77–9.83	9.81	0.03	0.01
	40–45	7.33–7.39	7.36	0.03	0.01
	45–50	10.81–10.86	10.84	0.02	0.01
Qal’at Salih	0–5	7.86–7.94	7.91	0.04	0.02
	5–10	13.51–13.55	13.52	0.02	0.01
	10–15	24.85–24.88	24.86	0.01	0.005
	15–20	17.61–17.70	17.64	0.04	0.02
	20–25	20.33–20.38	20.35	0.02	0.01
	25–30	9.45–9.55	9.51	0.05	0.02
	30–35	8.27–8.31	8.29	0.02	0.01
	35–40	19.52–19.60	19.55	0.04	0.02
	40–45	22.71–22.81	22.75	0.05	0.02
	45–50	6.23–6.31	6.26	0.04	0.02
Al-Majar	0–5	11.91–11.95	11.93	0.02	0.01

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2020.	5–10	18.25–18.27	18.26	0.01	0.005
	10–15	10.33–10.37	10.35	0.02	0.01
	15–20	23.52–23.55	23.54	0.01	0.005
	20–25	11.01–11.09	11.06	0.04	0.02
	25–30	26.72–26.74	26.73	0.01	0.005
	30–35	14.52–14.55	14.53	0.01	0.005
	35–40	16.33–16.35	16.34	0.01	0.005
	40–45	12.77–12.81	12.79	0.02	0.01
	45–50	15.26–15.31	15.28	0.02	0.01
Al-Amara	0–5	37.52–37.54	37.53	0.01	0.005
	5–10	28.32–28.36	28.34	0.02	0.01
	10–15	18.51–18.55	18.53	0.02	0.01
	15–20	41.21–41.24	41.22	0.01	0.005
	20–25	92.81–92.85	92.83	0.02	0.005
	25–30	67.13–67.19	67.16	0.03	0.01
	30–35	98.62–98.66	98.64	0.02	0.01
	35–40	114.12–114.15	114.13	0.01	0.005
	40–45	19.21–19.23	19.22	0.01	0.005
	45–50	14.71–14.75	14.73	0.02	0.01
Al-Kumait	0–5	9.52–9.57	9.55	0.02	0.01
	5–10	12.11–12.17	12.14	0.03	0.01
	10–15	7.44–7.48	7.46	0.02	0.01
	15–20	21.92–21.95	21.94	0.01	0.005
	20–25	16.70–16.90	16.80	0.10	0.05
	25–30	14.06–14.11	14.08	0.02	0.01
	30–35	25.31–25.36	25.34	0.02	0.01
	35–40	11.73–11.77	11.75	0.02	0.01
	40–45	6.56–6.61	6.58	0.02	0.01
	45–50	5.41–5.48	5.44	0.03	0.01
Ali Al-Sharqi	0–5	8.60–8.90	8.77	0.15	0.08
	5–10	13.01–13.08	13.05	0.03	0.01
	10–15	20.61–20.65	20.63	0.02	0.01
	15–20	10.41–10.44	10.42	0.01	0.005
	20–25	63.22–63.28	63.25	0.03	0.01
	25–30	29.32–29.37	29.35	0.02	0.01
	30–35	15.91–15.95	15.93	0.02	0.01
	35–40	9.72–9.77	9.74	0.02	0.01
	40–45	5.81–5.86	5.84	0.02	0.01
	45–50	4.44–4.53	4.49	0.04	0.02
Ali Al-Garbi	0–5	23.76–23.86	23.81	0.05	0.02
	5–10	31.01–31.05	31.03	0.02	0.01
	10–15	13.58–13.62	13.60	0.02	0.01
	15–20	14.31–14.35	14.33	0.02	0.01
	20–25	8.61–8.66	8.63	0.02	0.01
	25–30	12.49–12.53	12.51	0.02	0.01
	30–35	12.95–12.97	12.96	0.01	0.005

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2020.	35–40	11.41–11.46	11.43	0.02	0.01
	40–45	8.33–8.39	8.36	0.03	0.01
	45–50	10.41–10.46	10.44	0.02	0.01

The results in Tables (1) and Figure (2) shown concentrations of TPHs, Table (2) and Figure (3) reveal clear variations in the concentrations of TOC, While Table (3) shown grain-size characteristics in sediment core of the Tigris River. In general, the highest values were recorded in the surface depths, followed by a gradual decrease with increasing depth and, also in some cases, intermediate depths recorded a secondary rise. The joint influence of natural depositional processes and anthropogenic activities causes this vertical pattern. recent inputs of organic matter and pollutants originating from aquatic vegetation, algal production, domestic waste, and industrial discharges, and atmospheric deposition were the reason of the elevated surface concentrations [23], [9], [34]. with sediment depth increases, TOC and TPHs typically diminish as a result of microbial decomposition and compaction; however, a fraction of more recalcitrant organic carbon is likely to continue in anoxic environments. [35], [36], [37].
The heist of TPH concentrations (114.13 ug/g) at depth (35-40 cm) recorded Al-Amara station, with highest of TOC values, which conferred the large impact of urban and industrial activities, with limited aquatic renewal that facilitates the accumulation of pollutants [38]. At Ali Al-Sharqi, a peak of TPH (63.25 ug/g) was observed at the depth (20-25 cm), which can be attributed to the leakage of diesel fuel from fishing vessels in the area [39]. on the other hand, Al-Kumait showed the most elevated of TOC levels (reaching up to 10.73%), which can be attributed to the abundance of fine-grained, organic-rich sediments which have a significant adsorption capacity [40]. At the same time, Qal'at Salih and Ali Al-Garbi documented the minimal hydrocarbon concentrations because of their geographical distance from principal urban or industrial influences. decrease of persistent hydrocarbons over time within these stations belong to the affected by Natural processes, such as microbial degradation, volatilization, and photodegradation. [2], [41], [42]. Al-Majar and Al-Uzair stations recorded intermediate concentrations as a result of attributed to agricultural drainage practices and limited local effluents of water [43]

Grain-size composition plays the critical role of the regulation of pollutant retention, as fine-grained sediments have greater surface areas and superior electrostatic features, which facilitate a more extensive adsorption of organic materials. [44].
At most sampling locations the results shown a dominance of fine-grained sediments, consisting of silt and clay, increasing of 70% of the overall composition. That's mean the deposition occurring under low-energy hydrodynamics conditions, which facilitate the accumulation of organic matter and contaminants. [45], [46]. as shown at Al-Uzair and Al-Kumait station which consist of primarily characterized by silty clay and silty clay loam. In contrast, Qal'at Salih and Al-Majar reveal a gradation of textures transitioning from clay loam to sandy clay loam, thus reflecting the energy of the hydrodynamics in these stations was higst than the other stations. [47]. At Al-Amara station, the dominance of clay loam is clear, the precens of sandy loam at the depth between (20–30 cm) indicate to the occurrence of accidental high-energy phenomena such as flood events or reworking of sediment processes [48]. In contrast, the presence of high-energy depositional environments connected with flash floods and surface runoff originating from the eastern highlands in Iran at Ali Al-Garbi station shows sandy loam and loamy sand, with sand content reaching 82.6% [49], [50].
Overall, there is a dual mechanism regulating contaminant spread within sediment matrices as indicated in the results. The primary factor is anthropogenic pollution sources, which include

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industrial and urban effluents, which cause the heightened concentrations detected in surface sediment depths. [9], [34], [6]. The second factor relates to the sedimentological and geochemical characteristics including fine-grained texture, increased total organic carbon, organo-mineral interactions, and anoxic conditions, which assist the retention of pollutants in subsurface depths. [36], [23], [35]. There by rendering these factors as valuable metrics for evaluating the ecological condition of the sediments within the Tigris River. [51], [52], [24].

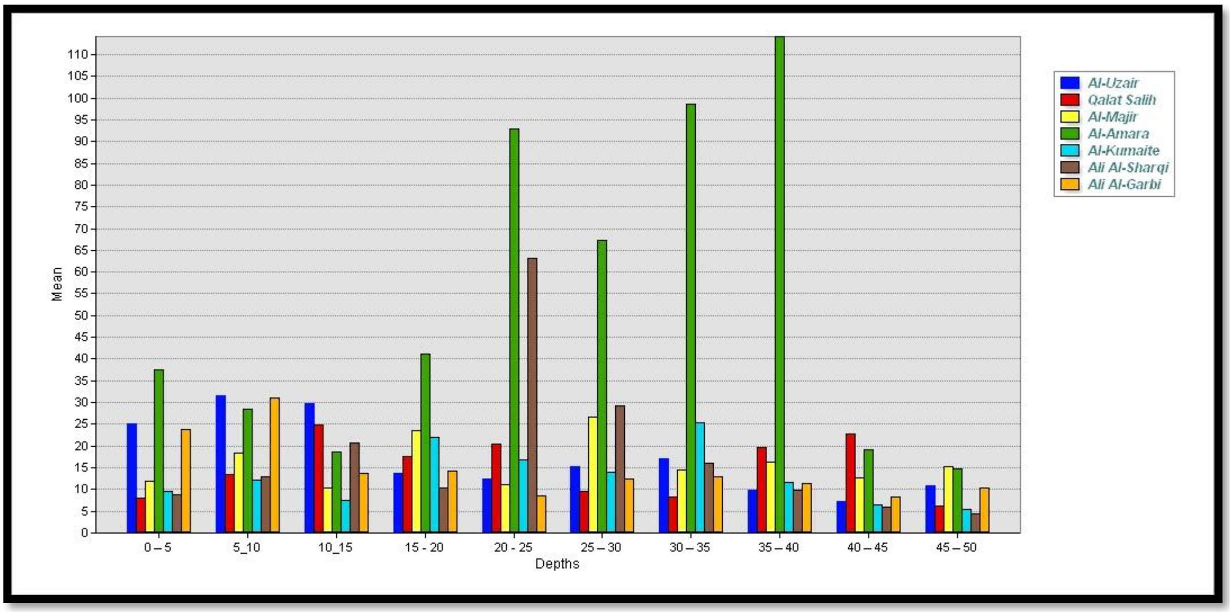

Fig. 2: Mean of TPHs concentrations (μg/g) with depths across the study area stations.

Table 2: Total organic carbon (TOC%) within core sediment of the study stations.

Station	Depth (cm)	TOC (%)	Range (%)	±SD	±SE
Al-Uzair	0–5	6.06	5.98–6.20	0.12	0.06
	5–10	6.36	6.00–6.70	0.35	0.20
	10–15	6.43	6.20–6.80	0.32	0.18
	15–20	5.73	5.50–6.00	0.25	0.14
	20–25	5.76	5.70–5.80	0.05	0.02
	25–30	5.13	4.90–5.50	0.32	0.18
	30–35	3.46	3.40–3.60	0.11	0.06
	35–40	3.20	2.80–3.50	0.36	0.20
	40–45	5.10	5.00–5.20	0.10	0.05
	45–50	4.33	4.10–4.60	0.25	0.14
Qalat Salih	0–5	6.06	6.00–6.20	0.11	0.06
	5–10	4.80	4.40–5.10	0.36	0.20
	10–15	3.33	3.20–3.50	0.15	0.08
	15–20	2.10	1.90–2.40	0.26	0.15
	20–25	2.26	2.00–2.50	0.25	0.14
	25–30	4.33	4.00–4.60	0.30	0.17
	30–35	6.30	6.00–6.50	0.26	0.15
	35–40	3.20	3.00–3.50	0.26	0.15
	40–45	3.36	3.20–3.50	0.15	0.08

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2020.	45–50	1.66	1.30–2.00	0.35	0.20
Al-Majar	0–5	4.20	4.10–4.30	0.10	0.05
	5–10	5.36	5.00–5.80	0.40	0.23
	10–15	5.53	5.10–5.80	0.37	0.21
	15–20	5.50	5.20–5.80	0.30	0.17
	20–25	5.30	5.00–5.60	0.30	0.17
	25–30	4.63	4.40–4.80	0.20	0.11
	30–35	5.50	5.30–5.80	0.26	0.15
	35–40	5.73	5.60–5.80	0.11	0.06
	40–45	4.26	4.10–4.40	0.15	0.08
	45–50	5.80	5.70–5.90	0.10	0.05
Al-Amara	0–5	4.00	3.80–4.20	0.20	0.11
	5–10	3.76	3.50–3.90	0.23	0.13
	10–15	2.93	2.60–3.20	0.30	0.17
	15–20	3.00	2.80–3.20	0.20	0.11
	20–25	4.20	4.00–4.40	0.20	0.11
	25–30	3.16	2.90–3.50	0.30	0.17
	30–35	4.70	4.50–4.90	0.20	0.11
	35–40	5.10	4.90–5.40	0.26	0.15
	40–45	3.96	3.70–4.20	0.25	0.14
	45–50	3.16	3.00–3.40	0.20	0.11
Al-Kumait	0–5	9.00	8.90–9.10	0.10	0.05
	5–10	7.83	7.70–7.90	0.11	0.06
	10–15	8.76	8.60–8.90	0.15	0.08
	15–20	5.53	5.30–5.80	0.25	0.14
	20–25	5.63	5.30–5.90	0.30	0.17
	25–30	9.46	9.00–9.80	0.41	0.23
	30–35	10.73	10.60–10.90	0.15	0.08
	35–40	8.96	8.80–9.10	0.15	0.08
	40–45	6.73	6.70–6.80	0.05	0.02
	45–50	6.76	6.40–7.00	0.32	0.18
Ali Al-Sharqi	0–5	7.63	7.60–7.70	0.05	0.02
	5–10	9.13	9.00–9.30	0.15	0.08
	10–15	8.50	8.30–8.80	0.26	0.15
	15–20	6.70	6.60–6.80	0.10	0.05
	20–25	6.76	6.50–7.00	0.25	0.14
	25–30	7.33	7.10–7.60	0.25	0.14
	30–35	7.13	7.00–7.20	0.11	0.06
	35–40	8.10	7.90–8.40	0.26	0.15
	40–45	4.23	4.00–4.50	0.25	0.14
	45–50	3.43	3.30–3.60	0.15	0.08
Ali Al-Garbi	0–5	3.66	3.40–3.90	0.25	0.14
	5–10	4.26	4.00–4.50	0.25	0.14
	10–15	4.06	4.00–4.10	0.05	0.02
	15–20	4.46	4.20–4.80	0.30	0.17
	20–25	4.33	4.20–4.50	0.15	0.08

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2020.	25–30	3.26	3.00–3.60	0.30	0.17
	30–35	5.30	5.20–5.40	0.10	0.05
	35–40	4.60	4.40–4.90	0.26	0.15
	40–45	6.13	6.00–6.30	0.15	0.08
	45–50	4.33	4.20–4.40	0.11	0.06

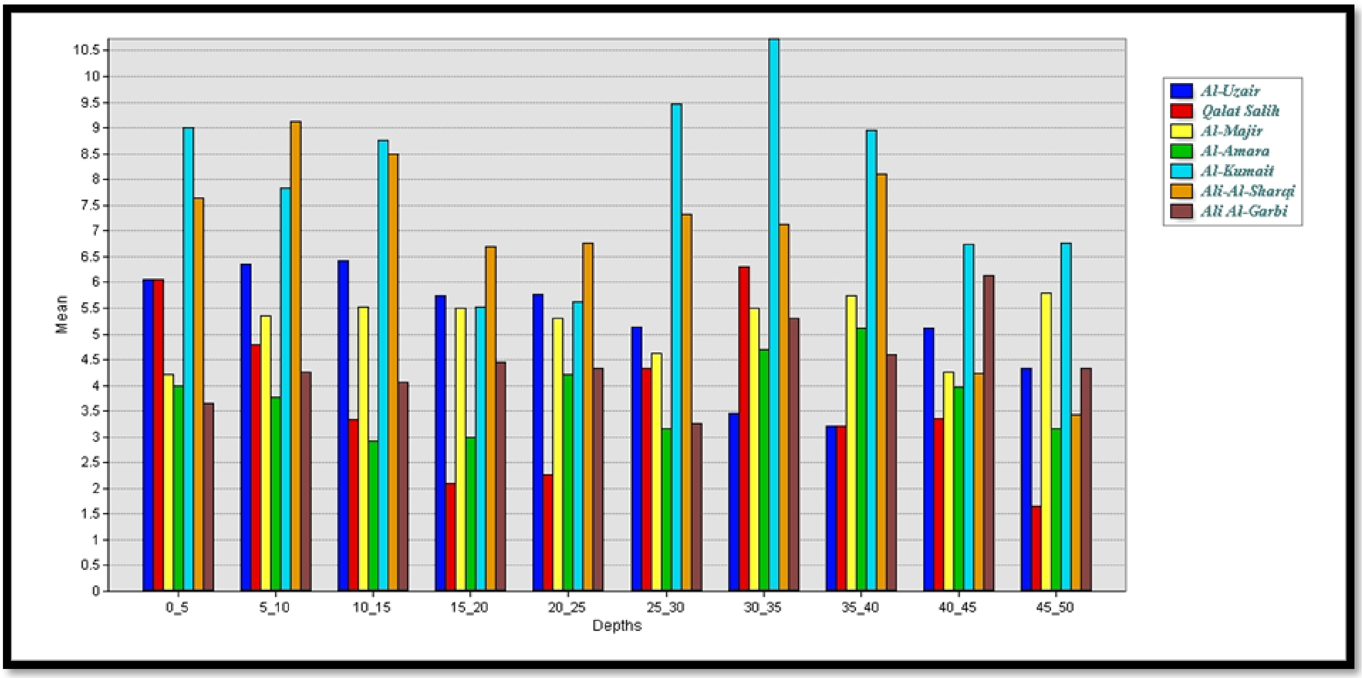

Fig. 3: Mean of TOC concentrations (%) with depths across the study area stations.

Table 3: Grain size and textural categorization of core sediment samples of the study stations.

Station	Depth (cm)	Soil Texture	Silt%	Clay%	Sand%
Al-Uzair	0-5	Silty Clay	49	49	1.99
	5_10	Silty Clay	45.84	50.01	4.15
	10_15	Silty Clay	46.8	50.87	2.32
	15-20	Silty Clay	52.8	42.24	4.96
	20-25	Silty Clay	46.18	50.2	3.62
	25-30	Silt Loam	64.09	21.36	14.54
	30-35	Loam	47.28	23.64	29.09
	35-40	Silt Loam	62.3	26.7	11
	40-45	Silty Clay Loam	63.46	30.64	5.9
	45-50	Silty Clay Loam	59.4	35.64	4.95
Qal'at Salih	0-5	Clay Loam	28	31.73	40.27
	5_10	Clay Loam	32.48	34.39	33.14

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2020.	10_15	Clay Loam	28.31	30.2	41.48
	15-20	Clay Loam	44.81	28	27.19
	20-25	Clay Loam	30.39	28.49	41.11
	25-30	Loam	26.4	20.75	52.85
	30-35	Clay Loam	34.43	36.45	29.12
	35-40	Clay Loam	25.68	39.51	34.8
	40-45	Clay Loam	29.46	29.46	41.08
	45-50	Clay	19.51	42.56	37.93
Al-Majar	0-5	Sandy Clay Loam	21.36	32.04	46.6
	5_10	Clay Loam	21.44	35.74	42.82
	10_15	Clay Loam	25.01	37.52	37.47
	15-20	Sandy Clay Loam	15.53	23.29	61.18
	20-25	Clay Loam	30.36	28.03	41.61
	25-30	Sandy Clay Loam	25.37	21.15	53.48
	30-35	Loam	28.52	23.77	47.71
	35-40	Sandy Clay Loam	20.61	20.61	58.77
	40-45	Sandy Clay Loam	25.6	23.63	50.76
	45-50	Clay Loam	31.5	31.5	37.01
Al-Amara	0-5	Clay Loam	23.66	37.85	38.5
	5_10	Clay Loam	25.16	32.03	42.81
	10_15	Clay Loam	32.65	32.65	34.7
	15-20	Clay Loam	29.5	27.39	43.11
	20-25	Sandy Loam	24.5	16.33	59.17
	25-30	Sandy Loam	21.37	19.23	59.4
	30-35	Clay Loam	30.7	28.51	40.79
	35-40	Clay Loam	33.09	35.3	31.61
	40-45	Clay Loam	30.3	34.96	34.74
	45-50	Clay Loam	26.57	28.78	44.64
Al-Kumait	0-5	Silty Clay	52.21	44.76	3.03
	5_10	Silty Clay	50.47	45.06	4.47
	10_15	Silty Clay	46.18	48.49	5.33
	15-20	Silty Clay Loam	50.79	37.62	11.58
	20-25	Silty Clay	45.46	41.83	12.74
	25-30	Silty Clay	45.34	45.34	9.32
	30-35	Silty Clay Loam	45.83	39.51	14.66
	35-40	Silty Clay	42.36	48.14	9.49
	40-45	Silty Clay	47.74	41.77	10.49
	45-50	Silty Clay	44.25	47.94	7.8
Ali Al-Sharqi	0-5	Clay Loam	32.81	28.71	38.48
	5_10	Clay Loam	33.12	38.97	27.91
	10_15	Sandy Clay Loam	19.54	29.31	51.15
	15-20	Loam	28.78	20.24	50.98
	20-25	Clay Loam	40.44	30.33	29.23
	25-30	Silty Clay Loam	42.92	32.19	24.89
	30-35	Clay Loam	41.56	32.91	25.53
	35-40	Clay Loam	36.63	30.53	32.84

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2020.	40-45	Clay Loam	31.14	41.51	27.35
	45-50	Clay Loam	27.42	27.42	45.15
Ali Al-Garbi	0-5	Sandy Loam	19.87	19.87	60.26
	5_10	Sandy Loam	17.51	11.67	70.81
	10_15	Sandy Loam	13.93	9.75	76.32
	15-20	Loamy Sand	9.96	7.75	82.54
	20-25	Sandy Loam	10.86	15.2	73.94
	25-30	Loamy Sand	9.76	7.6	82.64
	30-35	Sandy Clay Loam	12.28	20.47	67.25
	35-40	Sandy Loam	21.93	19.49	58.14
	40-45	Sandy Loam	19.45	21.45	59.1
	45-50	Sandy Clay Loam	25.13	23.8	51.08

Table (4) shows a comparison of TPHs concentrations from both previous studies and the current research. The comparative evaluation reveals that the TPHs concentrations in the sediments of the Tigris River (4.49 ug/g - 114.13 ug/g) correspond with the range of values chronicled in other studies, such as in the Shatt al-Arab, the northwestern Arabian Gulf, and several areas of southern Iraq. These results indicate similar sources of pollution, including industrial discharge, and urban runoff, exerting influence on these aquatic ecosystems which imply a consistent trend of hydrocarbon contamination.

Table 4: A comparative assessment of Total Petroleum Hydrocarbons (TPHs) from the current study with the previous study of Iraq.

Study area	Concentration (µg/g)	References
Shaft Al Arab and Northwest Arabian Gulf	0.108-37.02	[53]
Shaft Al Arab	275.433-28.821	[54]
Northwest Arabian Gulf	66.02 - 34.37	[55]
Shaft Al Arab and Estuary	148.42 - 59.52	[56]
Shaft Al Arab and Northwest Arabian Gulf	7.37-24.41	[57]
Iraqi coasts	2.39- 30.88	[58]
Shaft Al Arab	4.76-45.24	[34]
Banks of Shaft Ai Arab, Khor Al Zubair and Umm Qasr	0.94-26.27	[59]
West Qurna-2 Oil Field	14.82-41.86	[60]
local regions of southern Iraq	2.05-14.94	[61]
Shaft Al Arab, Tigris,Euphrates	1.39-10.83	[62]
Current study	4.49 - 114.13	Current study

Conversely, Table (5) gives a comparative evaluation of the values of Total Organic Carbon (TOC%) based on previous research and the present study. This analogy highlights that the values of TOC of the sediments in the Tigris River (1.66% -10.73) in the current study lie within the range of values of the same in other locations, such as the estuary of the Shatt al-Arab, the northwestern Arabian Gulf, and different parts of Iraq, implying the presence of similar environmental conditions and anthropogenic effects of the same on these water bodies.

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2020.

Table 5: A comparative assessment of Total Organic Carbon (TOC) from the current study with the previous study of Iraq.

Study area	TOC%	References
The estuarv of the Shatt al-Arab and the northwestern Arabian Gulf	0.813- 0.241	[58]
Shatt al-Arab River	8.34	[61]
Shatt al-Arab River	4.94-13.18	[63]
Shatt al-Arab River	0.48 -6.55	[64]
Shatt al-Arab River	5.98 -2130	[65]
Iraqi coasts	0.06 -1.03	[58]
Ozeem 1	332-0.22	[66]
Ozeem 2	4.2-0.72	
Shatt al-Arab River	5.48-12.69	[34]
The banks of the Shaft Al Arab. Khor Al Zubair. Umm Qasr	0.04-2.44	[59]
West Qurna-2 Oil Field	0.249-2.52	[60]
Arabian Gulf	0.04 -14.96	[67]
Shaft Al Arab. Tigris. Euphrates	15.11- 27.63	[62]
Tigirs river	1.66 - 10.73	Current study

Statistical Correlation

Table 6: Spearman's rank correlation coefficients about the variables present within the core sediment of the of the study area.

Variables	TPHs	TOC (%)	Silt%	Clay%	Sand%
TPHs	1.**	-0.187	-0.079	-0.093	0.108
TOC (%)	-0.187	1.**	0.399**	0.449**	-0.445**
Silt%	-0.079	0.399**	1.**	0.623**	-0.927**
Clay%	-0.093	0.449**	0.623**	1.**	-0.848**
Sand%	0.108	-0.445**	-0.927**	-0.848**	1.**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table (6) and Figure (4) explain the outcome of the Spearman correlation analysis performed in the light of TPHs, TOC, and fractions of sedimentary materials consisting of sand, silt, and clay. The findings imply that the correlation between TPHs and TOC is poor and statistically negligible (r = -0.187), which does not mean that the changes in the concentration of hydrocarbons are preconditioned only by the organic carbon content.in contrast, they are influenced by a number of other factors that include anthropogenic impacts, microbial degradation, and hydrodynamic

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characteristics of river networks [34], [9].

On the other hand, the analysis explains the existence of a major positive relationship between TOC and silt (r = 0.399) and clay (r = 0.449), and thus the assumption that organic matter is strongly connected with fine-grain sedimentary materials is supported. It is the high charge density and crystalline structure that enable such sedimentary structures to have high adsorption capacities and expansive surface areas, which make such structures helpful in retaining organic compounds. [44], [36]. Conversely, there is a strong negative relationship in TOC and sand (r = -0.445**), indicating that they have a lower capacity of retaining hydrocarbons and organic carbon, as shown in Ali Al-Garbi station. [49], [50].

Such empirical statistical data are in accordance with the field and laboratory observations when the locations of Al-Amara, Al-Kumait and Ali Al-Sharqi showed high levels of hydrocarbons and Total Organic Carbon (TOC) which confirm the presence of fine-grained sedimentary textures (silt and clay). The given observation supports the arguments expressed by [46] and [45], who stressed the initial significance of grain size in influencing geochemical conduct of sediments through controlling surface area and adsorption capability, which in turn affected the spatial distribution of hydrocarbons. The positive correlation between clay and silt (r = 0.623) and the negative correlation between sand and silt (r = -0.927) are further indicative of a natural facies gradient which captures changes in the current energy and depositional processes in the river [33], [51], [23], [35].

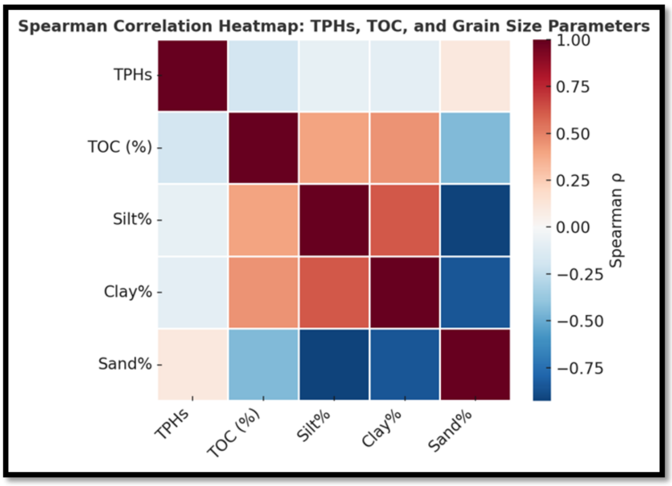

Fig. 4: Spearman Correlation Heatmap between variables in the study area station.

Conclusions

The paper shows that, the sediments present in the river Tigris in the Maysan Governorate are contaminated with Total Petroleum Hydrocarbons (TPHs), with significant spatial and vertical variations in the concentration (4.49 -114.13 ug/g). The patterns of the spatial distribution and accumulation of these hydrocarbons are not accidental; this is determined by a complex interaction of anthropogenic and natural determinists. Human-induced Effect is Preeminent: The high scores in TPH concentrations are directly linked to the distance to the pollution sources. The Al-Amara station has been the hardest hit by the urban and industrial effluents and the highest concentration as observed at Ali Al-Sharqi may be attributed to the sources that are localized like the diesel spillage caused by fishing ships. The grain size becomes a significant factor that

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contribute to retention of TPHs as well as Total Organic Carbon (TOC). Fine and organic rich sediments (silt and clay), as seen at Al-Kumait and Al-Amara, act as large reservoirs of pollutants as they have a true high adsorption capacity. On the other hand, the sandy and high energy setting like Ali Al-Garbi have lower contamination since the sediments are coarse thus, they hinder accumulation. The marginal and statistically insignificant association between TPHs and TOC indicate that it is not necessarily the presence of organic carbon per se that determines the concentration of hydrocarbons. This observation suggests that the recent anthropogenic inputs have a stronger significant contribution as compared to the natural sedimentary organic matter. The Vertical Distribution Reflects the Chronicle of contamination History: The vertical arrangement in the sediment cores can be regarded as an historical record of contamination, as newer layers usually represent current human influences, whereas the deeper layers indicate earlier events of contamination or a steady accumulation process in a declining environment.

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