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Evaluating the Environmental Impact of Industrial Activities on Soil in Basrah City, Southern Iraq

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Abstract

The study was conducted to assess and identify the spreading and concentration of polycyclic aromatic hydrocarbons and Total Organic Carbon in particular soils in some industrial sites in Basrah, southern Iraq: Siba Gas field, North Rumaila field, Basrah Gas Station, State company of Fertilizers, Shuaiba Refinery. Six soil samples were collected at a depth of 15 cm. The polycyclic aromatic hydrocarbon concentrations were determined using GC-MS, and the extraction process was done using a Soxhlet apparatus. Another significant factor influencing the distribution of aromatic compounds is the Total Organic Carbon content. The levels of Total Organic Carbon play a critical role in determining the availability and concentration of these compounds within the environment, as higher organic carbon content often correlates with increased production and preservation of aromatic substances. It was calculated using the Walkley and Black method. The highest concentration of polycyclic aromatic hydrocarbons was in the Al-Siba station, where the total concentration was 2.469 ppm. This high concentration of aromatic compounds is due to the presence of carcinogenic aromatic compounds (Chrysene, Naphthalene, 2-methyl, and 000090-12-0 Naphthalene) in high proportions in the soil of the Siba oil station. The lowest concentration of total aromatic compounds was about 0.559 ppm in the Fertilizer facility. The highest Total Organic Carbon% was found in the Shuaiba Refinery, North Rumaila, Basra Gas Station and Siba, whereas the lowest concentration was in the fertilizer factory as a result of the difference in the distribution of pollutants and oil spills.

Keywords: Polycyclic Aromatic hydrocarbons; pollution; TOC; Industrial facilities; Basrah

1. Introduction

Due to the direct effect on human health, soil pollution has become an important issue nowadays. So, many countries, international organizations and research institutions are investing significant resources and funds in addressing this matter. Soil acts as a corridor for pollutants created by people, like industrial and agricultural activities, that take these impurities from the surface down to the groundwater (Yaron and Calvet, 1996). Industrial waste especially affects how much soil can support living organisms since these poisons change fauna's quality and quantity (Mishra, 1989). These toxic substances may also be passed along the food chain, threatening creatures at a higher trophic level

(Mishra,1989). Many countries have been facing the challenges of pollution from petroleum industries. Polycyclic aromatic hydrocarbon (PAHs) comprises hydrocarbon compounds with carbon and hydrogen primarily arranged in multiple loops of aromatic nature. Some of these pollutants pose significant health risks, as they are widely distributed over sediments, soils, air, and fresh waters (WHO, 2010). Once released into the environment, especially water or soil, PAHs undergo different chemical processes such as oxidation, adsorption, photolysis and biodegradation (Sultana et al., 2014; Mahugija et al., 2015). Fire and smoke airborne discharges make up other leading sources of PAH exposure, especially for firefighters during their duties (Booze et al., 2004; Kirk and Logan, 2015). Especially in areas that contain many oil fields, such as Basrah, the Zubair field alone produces 490,000 barrels per day (Lazim et al., 2024). The West Qurna Oil Field has 21 billion stored within their reservoir (Mahdi et al., 2022). The compounds are formed especially by other artificial sources such as incinerators, industrial processes, power plants and coal-fired boilers, and last but not least, by traffic emissions such as exhaust cars (Hanedar et al., 2014; Slezakova et al., 2013a and b; Rifat et al., 2024; Ali et al., 2021; Ali and Azzat, 2022). Exposure to polycyclic aromatic hydrocarbons (PAHs) has been linked to an increased risk of various cancers, including lung, skin, urinary bladder, and gastrointestinal cancers (Boffetta et al., 1997; Rota et al., 2014). Additionally, PAHs can cause cellular damage through gene mutations (Kamal et al., 2015; Poirier, 2004), contribute to oxidative stress, and increase the risk of cardiovascular diseases (Burstyn et al., 2005; Lee et al., 2011). Among the many origins of these hazardous pollutants are industrial sites, oil spills, car exhaust emissions, and fossil fuel leaks (Rinawati et al., 2012). Also, to safeguard human health, especially that of children and the elderly, research on hydrocarbon pollution and buildup in industrial soils is necessary (Dao et al., 2010; Wei and Yang, 2010). The important previous studies in this area are (Al-Saad, 2000; Al-Hassen et al., 2013; Al-Saad et al., 2015; Al-Dabbas et al., 2015a, b; Ali et al., 2021; Ali and Azzat, 2022; Saleem et al., 2023; Abd Al-Qadir et el., 2023; Awadh and Al-Dabbas, 2024; Awadh and Al-Mimar, 2024; Resen et al., 2024). The study aims to identify the types of pollutants and assess the impact of industrial activities responsible for their generation.

2. Study Area

The study area is located in Basrah, within the Zubair Subzone, and is entirely covered by Quaternary sediments and recent soils. It was interesting in an important age of the geological history of Iraq because most of the Iraqi oils formed in that period (Al-Shawi et al., 2019) (Fig.1). The distribution of oil fields in southern Iraq is critical to the country’s economy, contributing significantly to national revenue and global oil supply. The study area represents the last stage of the tectonic stages witnessed by geological history, represented by the collision stage between the Arabian and Eurasian plates, which began in the Eocene age (Al-Kaabi et al., 2023; Maziqa et al., 2023). Soil samples are collected by using different methods and equipment, depending on the depth of the sediment layer and the nature of the site to be studied. Grab sampling is the simplest method of collecting surface soil directly using a shovel, trowel, or soil auger. Samples are often taken from various points across a designated area to ensure representativity. Fieldwork was carried out on December 3/12/2024, several industrials soil were chosen in different stations in Basra city, North Rumaila oil field, Fertilizer facility, Basrah Gas Company, Shuaiba A, B and Siba Gas field (SGF) (Figs. 1 and 2). Although limited in number, these samples were collected from diverse areas within the oil fields, providing valuable insights into the overall levels of pollution associated with these sites. Their geographic distribution enhances the understanding of pollution dynamics, offering a general perspective on the environmental impact of oil-related activities in the region.

3. Materials and Methods

Six soil samples with a depth of 15 cm were chosen. The oil waste impacted the locations received by vehicles and the presence of oil installations and oil spills. The locations of the studied sites were reported using a GPS device (Table 1), while the chemical analysis was done using some steps at Basrah University for Oil and Gas laboratories. The procedure used for the analysis of PAHs was reported by Goutex and Saliot (1980). Six grams of soil were sieved and then put in a cellulose thimble before being extracted using Soxhlet's intermittent extraction with a 120 ml solvent mixture composed of methanol and benzene (1:1 v/v) for 48 hours. A combination of extracts was then saponified at the same temperature for two hours using 15 ml of 4M MeOH (KOH), then cooling to room temperature. Using Sentinel-2 visual (Satellite image) and analyzing them in Arc Pro Map with up to 75% accuracy.

GC-MS analysis of the samples was conducted at the Basra Oil Company Laboratory (Nahran Omr) utilizing an Agilent Technologies 7890B GC system paired with an Agilent Technologies 5977A MSD equipped with an EI Signal detector. The analysis employed an HP-5ms column comprising 5% phenyl and 95% methyl siloxane (dimensions: 30 m x 250 µm x 0.25 µm). The oven temperature began at 40 °C for 4 minutes before increasing at 10°C/min to a final temperature of 300 °C, held for 20 minutes. The purge flow was set at 3 ml/min, with a helium carrier gas flow rate of 1 ml/min. The injection temperature was maintained at 290°C, and a sample volume of 0.5 microlitres was used with a split injection mode. Total Organic Carbon (TOC) analysis was done following the method Walkley and Black (1934) gave at the Marine Science Center.

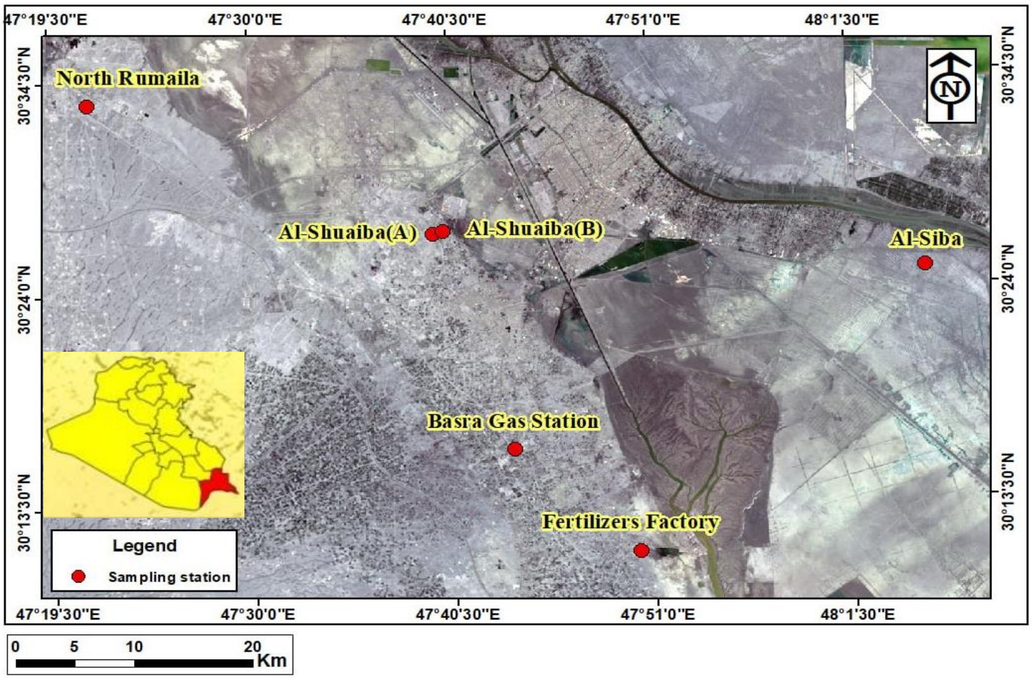

Fig.1. Location map for the studied stations in Basrah city

Table 1. Soil Sample Stations and their Geographic Coordinates

Sampling stations		Latitude	Longitude
Al-Shuaiba	A	30.446957	47.660117
	B	30.44898	47.669272
Basra Gas Station		30.269361	47.727732
Fertilizers Factory		30.183146	47.836327
Al-Siba		30.4142405	48.0918427
North Rumaila		30.5576506	47.3586246

Fig.2. Photos of the studied stations showing the effective soils in oil pollution, BGC: Basra Gas Company, Siba Gas Company, SCF: State Company of Fertilizers. Most of the soils are classified as Class B – Light to Medium Distillates)

4. Results and Discussion

Differences in the sedimentary environment can be reflected in the relative content and chemical and physical characteristics of terrigenous and chemical sedimentary deposits in the Quaternary period (Al-Jaberi and Mahdi, 2020) and the elements added to the soil by industrial pollutants. In the analysis of total organic compounds, it was observed that the Al-Shuaiba A sample exhibited the highest concentration (14.928), attributed to the prevalence of elevated organic matter in the region due to the widespread distribution of pollutants within the study area. This finding underscores the impact of environmental factors on organic compound levels. Subsequently, the concentrations in the Siba and Rumaila samples were determined (5.339 and 8.200). Displaying variations in comparison to the Al-Shuaiba A sample. Notably, the fertilizer plant sample exhibited the lowest concentration among the analyzed samples (0.636). This discrepancy suggests the influence of specific sources and localized activities on organic compound levels (Table 2).

Table 2. TOC Levels at Different Locations

Location	TOC%
Basra Gas Station	6.843
Al-Siba	5.339
North Rumaila	8.200
Al-Shuaiba A	14.928
Al-Shuaiba B	6.145
Fertilizer factory	0.636

Total concentrations of polycyclic aromatic hydrocarbons at six stations extended from 2.469 ppb in Al-Siba station to 0.559 ppb at the Fertilizer facility station and showed predomination of high molecules weight, which were Chrysene, Naphthalene, 2-methyl and 000090-12-0 Naphthalene in Al-Siba station. The small molecular weights with 2-3 fused rings predominate in soil stations, and they are Fluorene Phenathrene Acenaphthylene. The highest total PAH concentration was observed at the Al-Siba station primarily due to elevated levels of Chrysene (0.535 ppb), a recognized carcinogen, along with significant contributions from Phenanthrene (0.301 ppb) and Naphthalene, 2-methyl- (0.442 ppb) HMW. These elevated PAH levels are likely attributable to extensive industrial activities, including the presence of pollutants from oil spills, inadequate measures to reduce spills and insufficient safety protocols. Additional factors contributing to high PAH levels at Siba include industrial waste, oil residues, vehicle exhaust emissions, and spills from equipment. Carcinogenic compounds such as Chrysene pose serious health risks, including an increased potential for cancer upon prolonged exposure. Conversely, the Fertilizer Facility recorded the lowest total PAH concentration (0.559 ppb), largely due to lower values of compounds like Naphthalene (0.029 ppb) and Benzo[b]fluoranthene (0.006 ppb). This suggests that the facility either engages in less intensive industrial operations than other sites or has effectively implemented pollution control measures. Reasons for the lower PAH levels at the Fertilizer Facility may include the use of cleaner production technologies, stringent environmental regulations, regular maintenance of equipment to prevent leaks and spills, and effective waste management practices that minimize the release of PAHs. These measures significantly reduce PAH levels, demonstrating a proactive pollution control and environmental protection approach. Nevertheless, the control of compounds with high molecular weights was Pyrene, Benzo[b] Fluoranthene, Chrysene, and Benzo[k] fluoranthene in all stations (Table 3).

Table 3. Polycyclic Aromatic Hydrocarbon Concentrations (PAH)

Component	**The Stations**					
	Rumaila	Fertilizer facility	Basrah gas	Shuaiba	Shuaiba	Al-Siba
Naphthalene	0.002	0.029	0.113	0.141	0.115	0.248
Naphthalene, 2-methyl-	0.040	0.244	0.324	0.262	0.151	0.442
000090-12-0 Naphthalen...	0.074	0.249	0.365	0.262	0.159	0.460
000208-96-8 Acenaphthy...	ND	0.0005	0.002	0.001	0.002	0.002
Acenaphthene	0.028	0.012	0.036	0.012	0.018	0.095
Fluorene	0.074	ND	0.045	ND	0.055	0.169
Phenanthrene	0.577	0.006	0.312	0.133	ND	0.301
Anthracene	ND	ND	0.011	0.002	0.004	ND
Fluoranthene	ND	0.003	0.004	0.052	ND	ND
Pyrene	ND	ND	0.017	0.063	0.024	ND
000056-55-3 Benz[a]ant...	ND	0.0002	0.004	0.022	0.0002	ND
000218-01-9 Chrysene	0.259	ND	ND	ND	0.024	0.535
000205-99-2 Benzo[b]fl...	0.002	0.006	0.009	0.085	0.008	0.016
Benzo[k]fluoranthene	0.006	0.0001	0.004	0.014	0.436	ND
000050-32-8 Benzo[a]py...	ND	0.001	0.008	0.010	0.632	0.034
000193-39-5 Indeno[1,2...	0.006	0.002	0.008	0.044	0.004	0.012
000053-70-3 Dibenz[a,h...	0.054	0.002	ND	0.024	0.059	0.038
Benzo[ghi]perylene	ND	0.004	0.002	0.099	0.244	0.117
Total	1.122	0.559	1.264	1.226	1.935	2.469
S. D	0.174	0.088	0.130	0.085	0.180	0.189

Figs. 3 and 4 verified the variation of polycyclic aromatic hydrocarbon concentration as curves in gas chromatography devices and showed variations between the concentrations of HMW and LMW in all soil stations due to the different soil sources of pollution in the study stations.

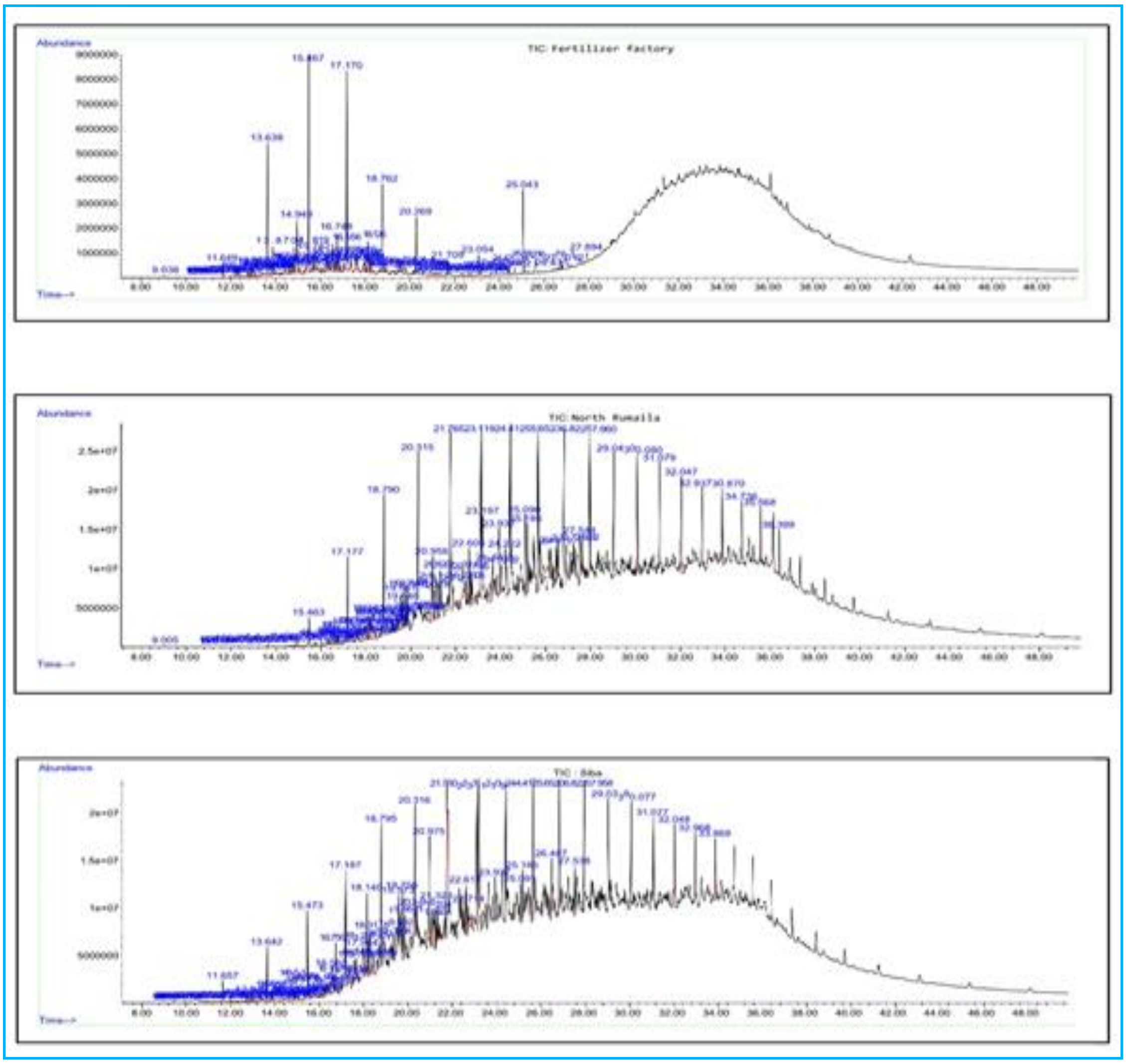

Fig.3. Concentrations of PAHS in the current study, dry weight using a gas chromatography device

The PAHs concentrations in different stations are presented in Figs. 5 and 6. According to the data, ArcPro maps show areas of PAHs measured at industrial station sites (Fig. 7), and the percentage of validation reaches 75%. The findings from several stations showed that polycyclic aromatic hydrocarbons which are a class of complex substances have been found to be widespread with most of them being carcinogenic varieties such as Chrysene, Naphthalene, 2-methyl, and 000090-12-0 Naphthalene especially at Al Siba station. Basrah city is extensively affected by oil pollution related to petroleum waste discharges into the soil and widespread spillage caused by oil companies. Furthermore, major oil refineries gas production plants and oilfields (crude oil extraction and production sites) pose significant pollution risks to human health. Moreover, Basrah city is environmentally affected by petroleum waste from petrol spills in garages, petroleum byproducts dumping on lands tanks or tanker truck leaks, and other activities that occur at construction sites for residential houses, power generating stations including electrical generating plants, residential areas, workshops (Al-Saad et al., 2015).

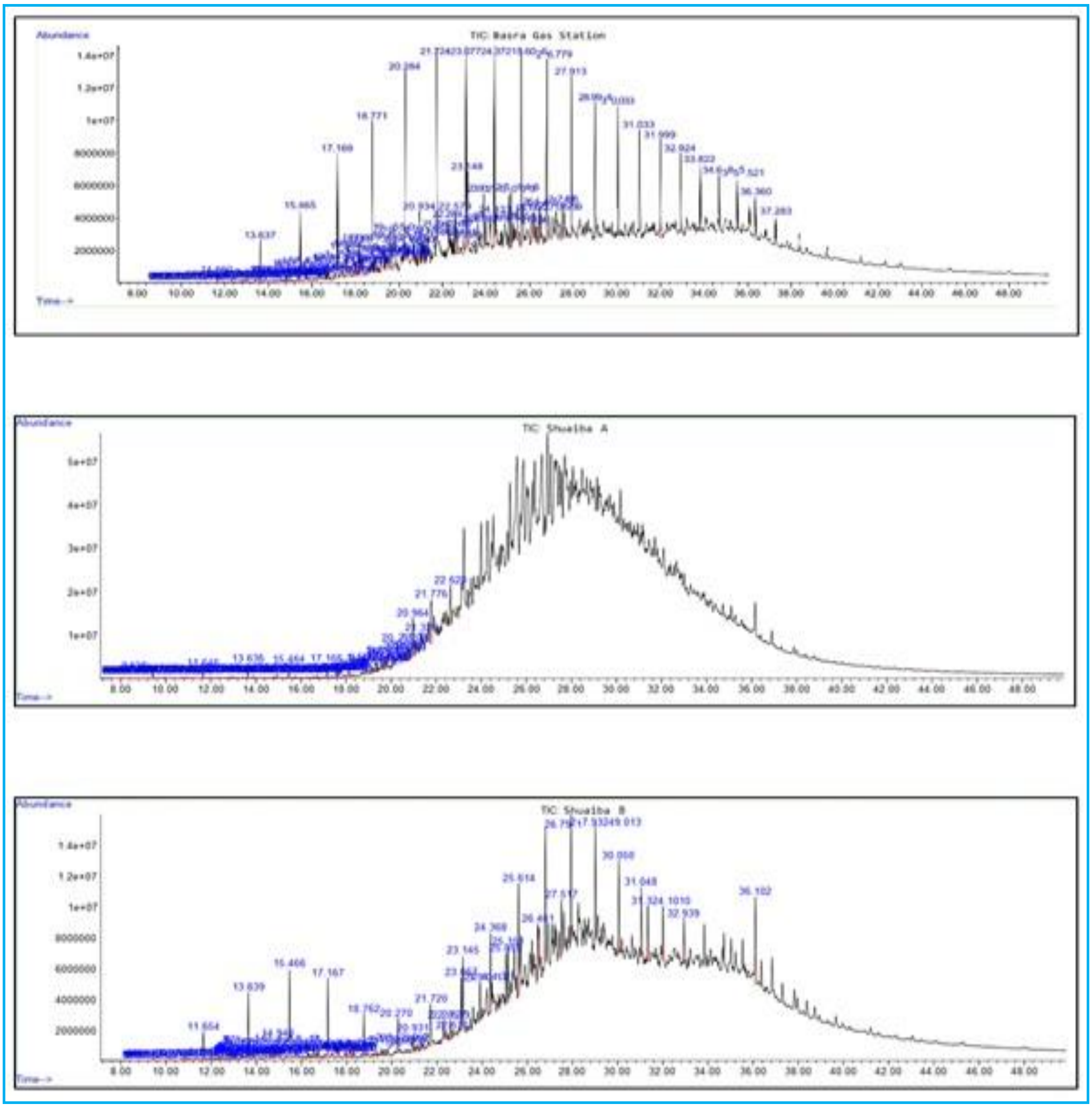

Fig.4. Concentrations of polycyclic aromatic hydrocarbons (PAHS) in the current study, dry weigh using a gas chromatography device

Table 4. Comparison with of PAHs carcinogenic Values in the international studies

Comp Ref	ap	ACY	ACE	FLU	PHE	ANT	FLU A	PYR	B(a)A	CHR	B(b)F	B(k)F	B(a)P	Dib	Ind	B(ghi)
WHO & IPCS, 1998.	±	±	±	–	±	–	–	±	±	+	+	±	+	+	±	–
USEPA, 2009	140	-	3400	2300	-	17000	-	1700	0.15	15	0.15	1.5	0.015	0.015		
Italian Leg., 1999	-	-	-	-	-	-	-	5	0.5	5	0.5	0.5	0.1	0.1	0.1	0.1
Netherlands	0.14	-	-	-	0.51	0.12	2.6	-	0.25	10.7	-	2.4	0.26	-	-	7.5

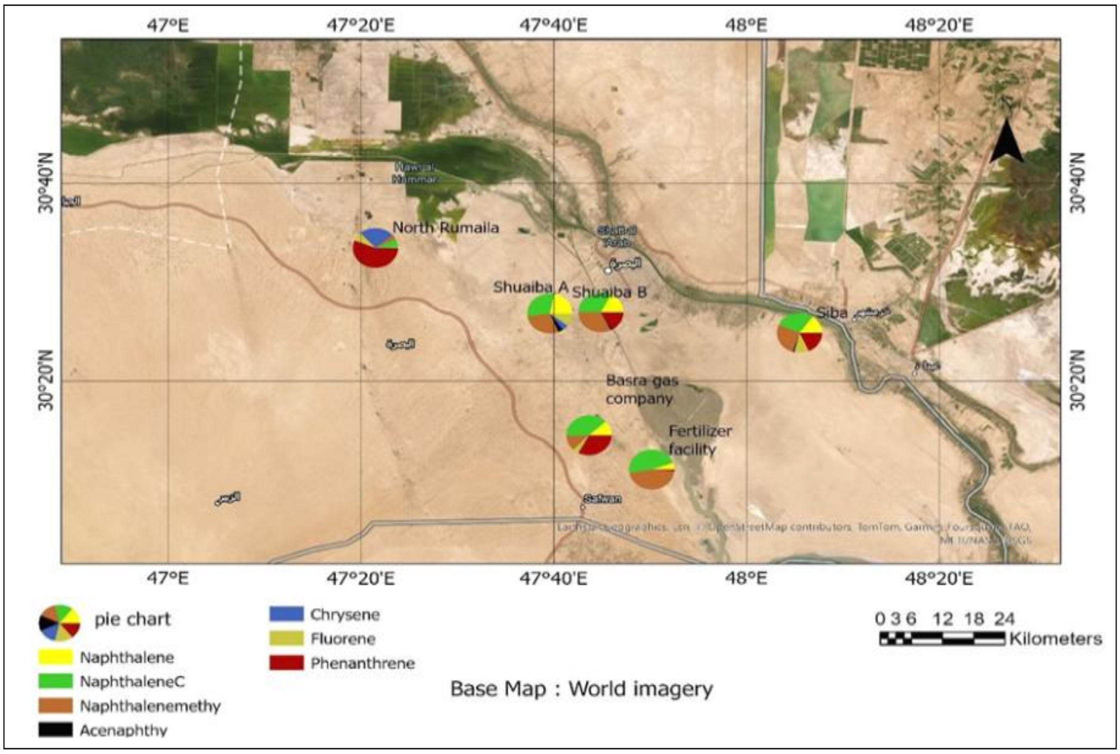

Fig. 5. Variation in the distribution concentration of PAHs according to sites using the ArcPro map as Pie Chart

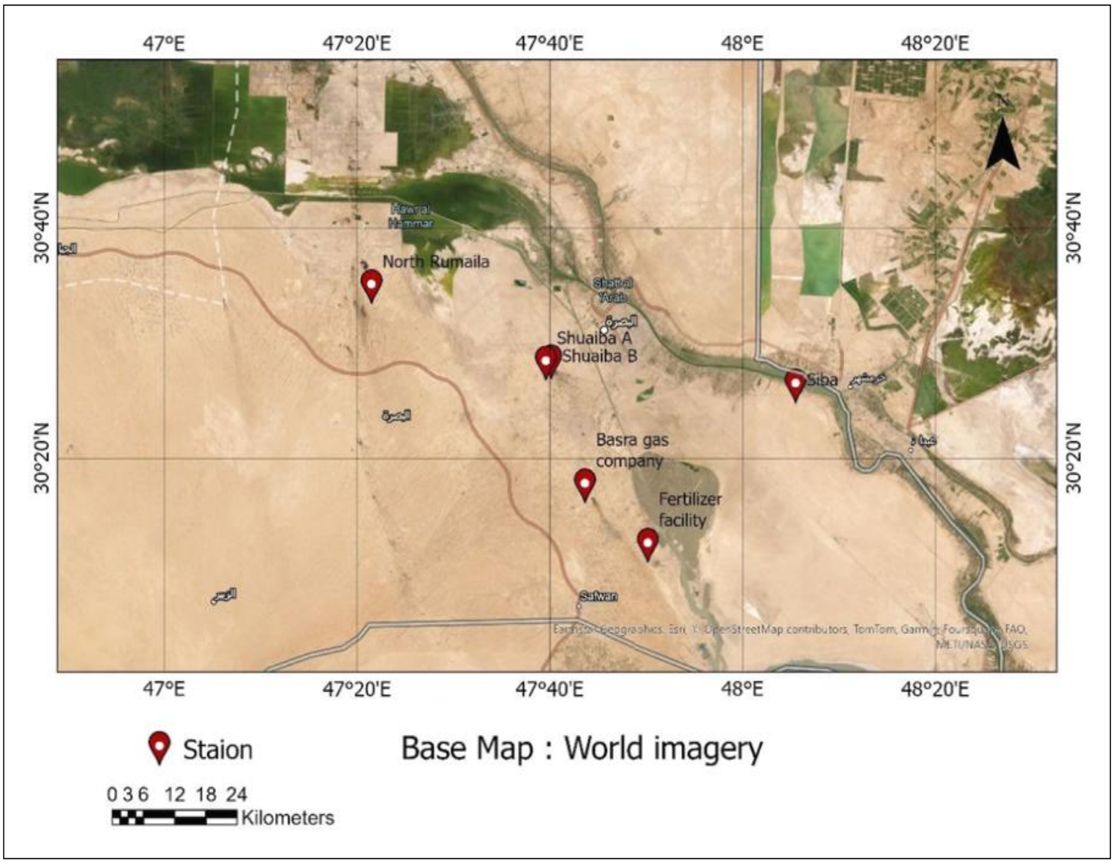

Fig. 6. Variation in the distribution concentration of PAHs according to sites using the ArcPro map

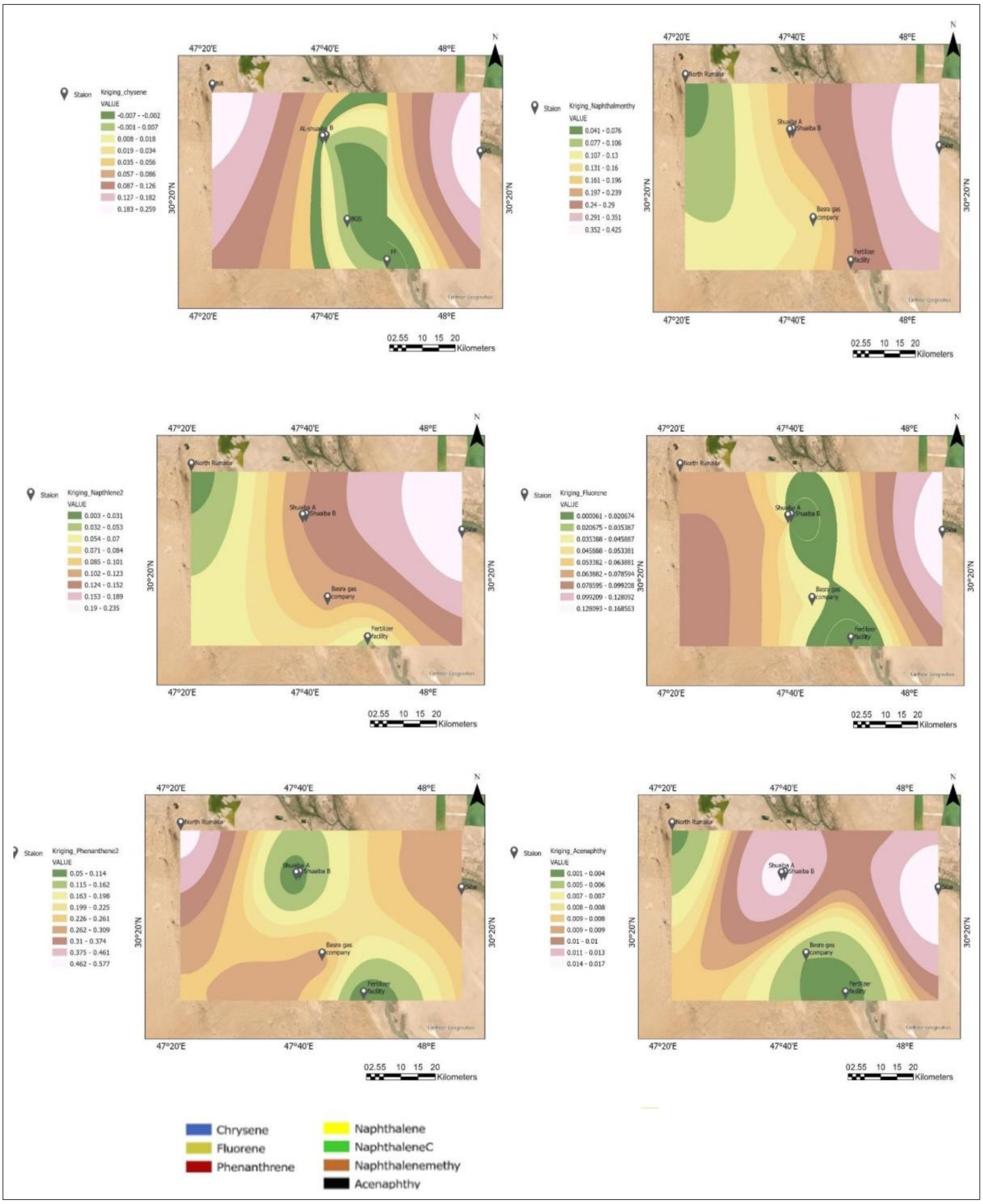

Fig. 7. Variation in the concentration of PAHs in soil stations using the ArcPro maps

5. Conclusions

The environment is host to numerous compounds known as polycyclic aromatic hydrocarbons (PAHs), alongside other pollutants arising from both natural processes and human activities. Elevated levels of PAHs in soil indicate significant petroleum hydrocarbon sources. The high concentration of PAHs can be attributed to a combination of anthropogenic and natural influences. In light of our PAH data, Basrah is confronting a severe environmental crisis exacerbated by widespread oil pollution due to substantial spills and the negligent disposal of petroleum waste. The adverse effects of this pollution are further intensified by health risks associated with the operations of large oil refineries, gas production facilities, and oilfields involved in crude oil extraction. Moreover, various factors contribute to this grim situation, including petroleum waste from garage spills, leaks from tanker trucks, and the improper disposal of petroleum byproducts in land tanks. Other activities, such as those occurring at residential construction sites, power generation plants, and workshops, also play a role in Basrah's pervasive pollution. The cumulative impact of these elements poses significant threats to the region's environmental health and public well-being. Despite its rich oil reserves, the region faces challenges, including environmental concerns and the need for improved infrastructure and investment to reduce the risk of pollution.

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