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Investigating N-Alkane Distribution in the Soils of the Basrah's Oilfield: Sources and Environmental Impact

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Abstract - Soil samples were collected at a depth of 0 to 20 cm from 11 oil fields in the Basrah governorate (Seba, Safwan, Majnoon, Ratawi, Bergezia, West Qurna2, West Qurna1, Shuaaba, South and North Rumaila, and Al Zubair). The analysis of every hydrocarbon component was done using gas chromatography and a flame ionization detector. Total n-alkanes have the highest mean concentrations in soil (341.666µg/g dry weight) at Station 7, and the lowest mean concentrations (178.874µg/g dry weight) at Station 4. The CPI readings range from 0.251 in the spring at Station 8 to 1.880 in the summer at Station 5. When the CPI value is more than one, it suggests that the n-alkanes originated biogenically from bacteria, algae, and the wax found on the leaves of vascular higher plants. The C17/Pristane and C18/Phytane Ratios, which show the source of alkanes in soil, indicated that the petroleum had weathered and become older in the soil, whereas the majority of soil samples included isoprenoids, such as phytane and pristane. There were also cases of Unresolved Complex Mixture (UCM). The findings showed that the aliphatic hydrocarbons came from both biogenic and anthropogenic sources. N-alkane distribution is bimodal: odd carbon numbers (C21, C22, C23, C24, and C25) predominate in the Low Molecular Weight (C13-C25) and indicate bacterial activity, while odd carbon numbers (C29, C30, C31, and C32) predominate in the High Molecular Weight (C26-C36), suggesting a source of higher plant wax. Both biogenic and manmade factors contributed to the majority of the oil field.

دراسة توزيع الالكانات الطبيعية لترب حقول النفط في البصرة: المصادر والاثر البيئي

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المستخلص - تم جمع عينات التربة على عمق يتراوح بين 0 إلى 20 سم من 11 حقلاً نفطيًا في محافظة البصرة (السيبه، سفوان، مجنون، ارطاوي، البرجسيه، غرب القرنة 2 ، غرب القرنة 1 ، الشعيبة، الرميلة الجنوبية والشمالية، والزبير). تم إجراء تحليل كل مكون من مكونات الهيدروكربون باستخدام كروماتوغرافيا الغاز وكاشف تأين اللهب. تحتوي الألكانات الطبيعية الكلية على أعلى متوسط تركيز في التربة 341.666 ميكروجرام / جرام وزن جاف) في المحطة غرب القرنة 1 ، وأقل متوسط تركيز 178.874 ميكروجرام / جرام وزن جاف) في المحطة ارطاوي. تتراوح قراءات مؤشر نسبة المكون العضوي من 0.251 في الربيع في المحطة الشعيبة إلى 1.880 في الصيف في المحطة البرجسية. عندما تكون قيمة مؤشر نسبة المكون العضوي أكثر من واحد، فهذا يشير إلى أن الألكانات الطبيعية نشأت بيولوجيًا من البكتيريا والطحالب والشمع الموجود على أوراق النباتات الوعائية العليا. أشارت نسب C17/Pristane وC18/Phytane، التي توضح مصدر الألكانات في التربة، إلى أن البترول قد تعرض للتآكل وأصبح أقدم في التربة، في حين تضمنت غالبية عينات التربة إيزوبرينويدات، مثل الفيتان والبريستان. كانت هناك أيضًا حالات من خليط معقد غير محلول UCM. أظهرت النتائج أن الهيدروكربونات الأليفاتية جاءت من مصادر حيوية وبشرية. توزيع N-alkane ثنائي النمط: تسود أرقام الكربون الفردية

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C21 و C22 و C23 و C24 و C25) في الوزن الجزيئي المنخفض (C13-C25) وتشير إلى النشاط البكتيري، بينما تسود أرقام الكربون الفردية (C29 و C30 و C31 و C32) في الوزن الجزيئي المرتفع (C26-C36) ، مما يشير إلى مصدر شمع نباتي أعلى. ساهمت العوامل الحيوية والبشرية في غالبية حقل النفط.
الكلمات المفتاحية: الألكانات الأعتيادية، تلوث التربة، الحقول النفطية، البصرة، جنوب العراق

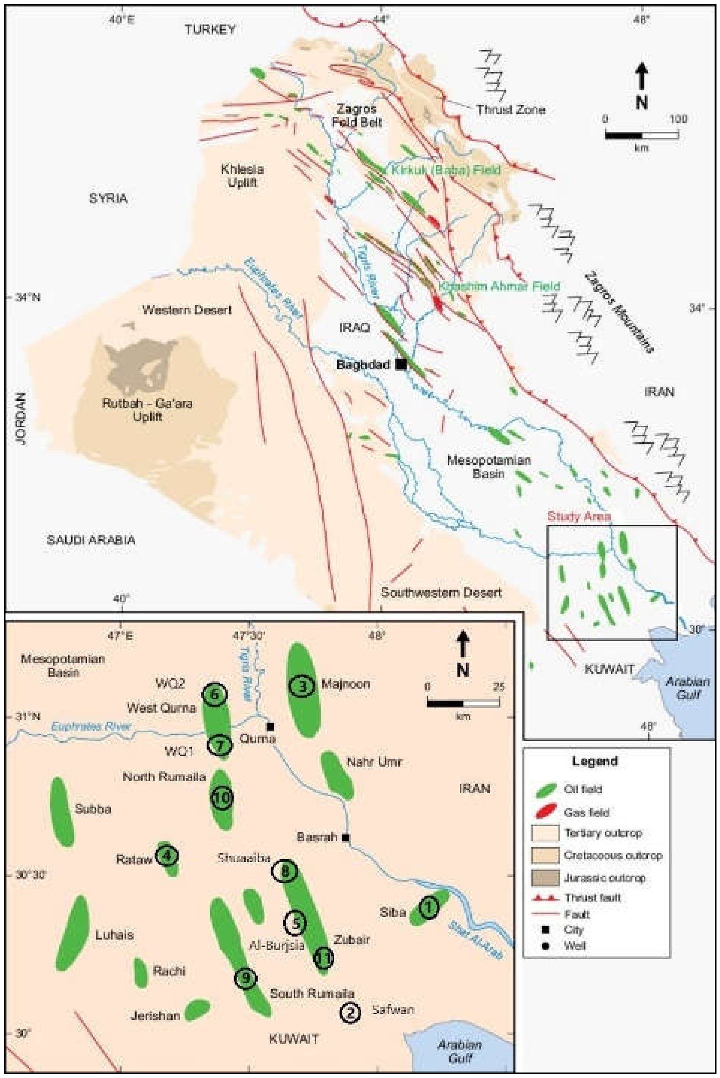
Introduction

N-alkanes, sometimes referred to as normal alkanes, are hydrocarbons with a straight chain that are made up of hydrogen and carbon atoms. They are a major constituent of natural gas and crude oil and are distinguished by their unbranched, basic structure. The length of n-alkanes varies, ranging from very long chains to short chains like methane (CH_4). Alkanes often have the formula CnH2n+2 where n is the number of carbon atoms. When evaluating the source and level of petroleum hydrocarbon contamination, n-alkanes are a valuable set of indicators in environmental studies. They are essential for many industrial uses, such as lubricants, fuels, and starting materials for chemical synthesis. Petroleum hydrocarbons contain a large number of aromatic compounds, heavy asphaltene compounds, and almost equal numbers of n-alkanes with odd and even carbon atom counts. The hydrocarbons which make form the crude oil fraction have n-alkanes as their most prevalent single component. The majority of crude oil's liquid component is made up of alkanes, which are typically liquid at room temperature and have carbon numbers of at least around C12. Alkane mixes can differ significantly and are dependent on the oil's source as well as the chemical structures' experiences with different processes such biodegradation, microbial activity, and spillage.

As a result, the study of natural and environmental materials often uses alkanes as molecular components. Alkanes are complex mixtures, with the exception of the volatile, lower-carbon molecules (carbon numbers less than about C8) (Zhan *et. al.*, 2022). The carbon chains length of n-alkanes in soil samples were recorded from C13-C40 (Al-Hejuje *et al.*, 2015). Numbers of other hydrocarbons compounds are present in the aliphatic fraction, including pristine and phytane. Normal alkanes are saturated hydrocarbons with both odd and even carbon counts (Wang *et al.*, 2015; Fagbote and Olanipekun, 2013). They can be used to evaluate petroleum contamination because they are organic molecules with photocatalytic properties that make up a significant fraction of crude oil (Cipa *et al.*, 2018). Two groups of n-alkanes, representing low-molecular-weight (LMW) compounds (C10-C20) and high-molecular-weight (HMW) compounds (C21-C40), were identified based on the chain length (Li *et al.*, 2021) The Carbon Preference Index (CPI) is the n-alkane concentration ratio of odd to even carbon numbers. "Even" carbon numbers are usually obtained from anthropogenic sources, whereas "Odd" carbon numbers are mostly generated from biogenic sources. Low Molecular Weight (LMW) n-alkanes are usually derived from marine biogenic sources, while High Molecular Weight (HMW) n-alkanes are usually derived from terrestrial vascular plants (Fagbote and Olanipekun, 2013). To determine the sources of hydrocarbons, many writers use particular indexes. These include the carbon preference index (CPI), which calculates the ratio of hydrocarbons with even and odd numbers of carbon atoms, the heptadecane to pristine ratio (C17/Pr), and the pristane to phytane ratio (Pr/Ph) (NRC, 2003; Ali *et al.*, 2013; Al-Hejuje, 2014). The class of saturated hydrocarbons known as normal alkanes, or n-alkanes, is characterized by their distribution patterns and the dominance of various C-numbers, which fluctuate based on the source matter's composition and geological changes (Wang *et al.*, 2015). All carbon atoms in a ring that have only one link between them and are made completely of carbon and hydrogen are referred to as cycloalkanes, and they are found in this class of hydrocarbons (Robert *et al.*, 2015). Environmental contaminants of the hydrocarbon type are considered important, especially in areas where oil is found. Soil contamination by hydrocarbons is a major problem in many oil-producing countries (Al-Saad *et al.*, 2015). Even this, most of the hydrocarbons present in soil are the result of human activities. The soil in Basrah Province is severely contaminated with oil pollutants, especially hydrocarbon compounds, normal alkanes (n-alkanes), and polycyclic aromatic hydrocarbons Saleem (2022) due to the abundance of oil fields, increased drilling and exploration activities, oil extraction and refinement processes, accompanying emissions of pollutants, and oil spills. Not only does air and water constitute essential components of soil, but they also contribute to direct soil contamination in addition to leaching and precipitation from the water. This study aimed to investigate the sources and concentration of n-alkanes in the soil of oil fields in Basrah, Iraq (Seba, Safwan, Majnoon, Ratawi, Bergezia, West Qurna1, West Qurna2, Shuaaba, South and North Rumaila and Al Zubair).

Materials and Methods

Eleven samples were taken near the oil field sites in Basrah city, (Seba, Safwan, Majnoon, Ratawi, Bergezia, West Qurna2, West Qurna1, Shuaaba, South and North Rumaila and Al Zubair) as depicted in Figure (1). During the period from July 2023 to March 2024, soil samples were seasonally collected. After rolling the samples with aluminum foil, they were brought to the laboratory for analysis. To extract the hydrocarbons from the soil, the procedures described by Grimalt and Olive (1993) and Wang *et al.* (2011) were followed. A 24 hours soxhlet extraction was carried out using 50 grams of dirt and 250 milliliters of methanol:benzen (1:1). In order to avoid sulfur interferences during the gas chromatographic separation, elemental sulfur was removed from the extracts using activated elemental copper. A chromatography column was then used to split the extracts into aromatic and aliphatic hydrocarbons. In order to prevent the top layer from being disrupted when the solvent was poured, 1 g of anhydrous sodium sulphate was added to the surface after 10 g of silica (100-200 mesh) and 10 g of alumina (100-200 mesh) were slurry packed. The silica and alumina were activated at 200°C for 4 hours and then partially deactivated with 5% water. The extract was then added to the column head, eluting 25 milliliters of hexane, yielding the aliphatic hydrocarbons. Using a rotary evaporator, the aliphatic fractions were concentrated and then transferred to a vial, where a stream of N_2 was used to precisely set the volume to 1 ml. Using an ally capillary gas chromatography with flash ionization detector (FID) on an aliquot of a 1 L extract of aliphatic, analyses were carried out. For two minutes, the Agilent 19091J-101HP-5 5%phenyl Methyl silicone column's temperature was maintained at 80°C. After that, it increased at a rate of 8°C per minute to 280°C for a duration of twelve minutes. Each distinct aliphatic was recognized using the retention duration of a real mixed standard that was acquired from Supelco, USA. The standard calibration curve of the relevant standard compounds was used to calculate the concentrations of aliphatic compounds. For compounds comprising aliphatic, recovery assays have a range of 80% to 92%. Replica analysis revealed that the standard deviation of the approach was less than 10%. Throughout the analysis procedure, great care was taken to prevent contamination of the samples. All solvents were double-distilled before use, and glassware was cleaned with distilled water and heated in an oven at 250°C for 24 hours. On the other hand, procedural blanks, which contained all of the reagents and glassware used during the investigation, were periodically found to have no significant interference.



(Figure 1) Samples Location.

Results and Discussion

The n-alkane carbon chains in soil samples were measured from C11 to C40. Numerous more hydrocarbon compounds, including pristine and phytane, were present in the aliphatic part. The seasonal values of n-alkanes in soil at the studied stations were represented in Tables (1-4). The following is a range of total n-alkane concentrations found in soil samples from eleven stations: station 1 from 138.261 µg/g during Summer to 326.832 µg/g during autumn. While in station 2 from 246.37 µg/g during winter to 380.084 µg/g during summer. Whereas in station 3 from 126.992 µg/g during summer to 499.247 µg/g during winter. In station 4 from 128.483 µg/g during summer to 243.341 µg/g during winter, while in station 5 from 157.094 µg/g during autumn to 461.636 µg/g during winter and at station 6 from 272.012 µg/g during autumn to 315.351 µg/g during winter. station 7 from 173.036 µg/g during summer to 651.333 µg/g during winter. Station 8 from 239.227 µg/g during winter to 315.088 µg/g during summer. Station 9 from 172.763 µg/g during summer to 373.923 µg/g during spring. Station 10 from 181.742 µg/g during autumn to 298.762 µg/g during summer and station 11 from 112.169 µg/g during summer to 414.921 µg/g during spring (Tables 1-4). The highest mean concentrations of total n-alkanes in soil (341.666 µg/g dry weight) are recorded at Station 7, while the lowest mean concentrations in soil (178.874 µg/g dry weight) are recorded at Station 4 (Table 5) and (Fig. 2) The winter season showed the highest concentrations, whereas the summer season showed the lowest amounts (Fig. 3) The GIS maps (Fig. 4) depict the concentrations of n-alkanes recorded during different seasons based on our data. The present investigation found that high molecular weight (HMW) n-alkane compounds exceeded low molecular weight (LMW) n-alkane compounds. This is because the low molecular weight (LMW) n-alkane compounds like C9-C16, can be readily evaporated or broken down by microorganisms, while the high molecular weight (HMW) n-alkane compounds like C28-C31, are more resistant to biodegradation (Al-Hejueje *et al.*, 2016). The current study's soil sample n-alkane carbon chain length range was (C11-C40). In the areas under study, carbon numbers C19 through C31 were predominant. The even n-alkanes in the range C12-C24 are attributed to the contribution of microorganisms and petroleum sources, whereas the domination of the odd n-alkanes in the range C15-C33 is a point to biogenic sources, particularly the (C23, C25, C27, C29 and C31) is an indicator to terrestrial plants (Wang *et al.*, 2011; Farid, 2017; Dong *et al.*, 2024) as shown in Figure (5). The extraction and production of crude oil in oilfields has led to an increase in n-alkane (Al-Saad *et al.*, 2015; Li *et al.*, 2021). The dominance of odd carbon n-alkanes (C15, C17 and C19) that are typically found in algae, model n-alkanes (C20 to C28) that maximize around C23 and can be combined by bacterial activity (Grimalt and Albaiges, 1990 ; Li *et al.*, 2016), and odd carbon number n-alkanes (C25 to C32) that are synthesized by higher plants are indicators of biogenic sources of hydrocarbons (Wang *et al.*, 2011).

The present study of spatial n-alkane results indicate that the highest concentration of n-alkanes was observed in winter at Station 7 (651.333 µg/g dry weigh), while the lowest concentration was observed in summer at Station 11 (112.169 µg/g dry weigh). Additionally, the mean concentration of n-Alkanes was found to be higher at Station 7 (341.666 µg/g dry weight) and lowest at Station 4 (178.874 µg/g) (Table 5).

Algae and phytoplankton are responsible for the odd carbon numbers that are present (Al-Saad, 1995; Wang *et al.*, 2015; Li *et al.*, 2022).

The presence of phytoplankton and algae is the source of the odd carbon (C15, C17 and C19) compounds in the aquatic environment (Law *et al.*, 1994; Cripps, 1995; Zhan *et al.*, 2022). According to Sakaria *et al.* (2008), the abundance of odd carbon n-alkanes C25, C27, C29 and C31 has been used as a monitor of organic material that comes from terrestrial plants (Thomas *et al.*, 2021). Additionally, Tynni (1983) and Chen *et al.* (2021) noted that the usual alkanes with an even carbon number originate from diatoms. However, bacterial activity was the source of C22 and C24 (Al-Bidhani *et al.*, 2020; Al-Khatib, 2008; Talal, 2008; Chen *et al.*, 2021). The low molecular weight n-alkanes, like C9-C15, in water can evaporate quickly or break down by microorganisms, while the high molecular weight n-alkanes, like C33-C36, are more resistant to biodegradation and can settle down in sediments. This could explain the undetectable values of C10-C15 and the low values of C16-C17.

As compared to phytane, which is typically found in oil, pristine is typically found in zooplankton (Guerra-García *et al.*, 2003).

In summer sediments, n-alkane total concentrations were often lower than those in winter. This may be due to rising temperature during summer which plays an important role in the evaporation processes of these compounds. During the summer, microorganisms in the sediments enhanced the biodegradation processes that also take place. While hydrocarbon compounds can biodegrade at a variety of temperatures, when temperatures decrease, the rate of biodegradation often decreases significantly (Al-Dossari, 2008). This result was agreed with Talal (2010) and Al-Khatib (2008).

Oil pollution affects Basrah City from a variety of sources, including: Connection with petroleum waste releases. The largest gas production plants, oil refineries, and additions to these stations served as the sites of crude oil extraction and production, or oilfields. Basrah City also received petroleum wastes from gas stations, leaks from tanks or tanker trucks, and the disposal of waste petroleum byproducts on the soil, as well as from transportation and industry activities, houses, workshops, and electrical generating plants and units (Al-Saad *et al.*, 2015). In general, wintertime soil concentrations of n-alkanes were higher than summertime concentrations. In the current study, the mean concentration of n-alkanes was found to be highest (327.351 µg/g dry weigh) in the winter and lowest (213.493 µg/g dry weigh) in the summer while spring is (266.400 µg/g) and autumn (252.251 µg/g). The seasonal mean concentration is arranged as follows (Table 5 and Fig. 3).

Winter > Spring > Autumn > Summer

This is due to changes in temperatures have a significant impact on the compounds' evaporation processes as well as the biodegradation processes carried out by bacteria and fungi. The rate of biodegradation of hydrocarbon compounds generally declines with decreasing temperature, despite the fact that they biodegrade throughout an extensive variety of temperatures (Al-Saad *et al.*, 2015; Shamshoom *et al.*, 1999; Leahy and Colwell, 1990; Hussain *et al.*, 1991; Al-Dossari ,2008). According to Williams *et al.* (2006), the most significant factor limiting the rates of microbial breakdown of hydrocarbons throughout the winter is temperature. Additionally, the weather affected the soil microbes' activities, which led to the hydrocarbons' breakdown. The high temperatures cause the highest rates of biodegradation of hydrocarbons. Therefore, the biodegradation of hydrocarbons proceeds more quickly in the warmer months whereas it proceeds more slowly in the colder months. Therefore, in Basrah city soils, biodegradation occurs fastest during the summer months. There was significant correlation between the n-alkanes in soil and TOC% ($r=0.175$, $p\geq 0.05$) that agrees with (Al-Mahana, 2015; Kareem, 2016; Kadhim, 2019) they found a significant correlation between the n-alkanes in sediments and TOC%. While there is non-significant correlation between the n-alkanes and grain size of soil (sand, silt) exapte clay r= (0.381), as shown Table (6). The CPI readings range from 0.251 in the spring at Station 8 to 1.880 in the summer at Station 5. When the CPI value is more than one, it suggests that the n-alkanes originated biogenically from bacteria, algae, and the wax found on the leaves of vascular higher plants (Gao *et al.*, 2007; Pu *et al.*, 2017; Wang *et al.*, 2018) The ratio of Pristane to phytane ranges from (0.089) in the spring at Station 4 to (2.449) in the winter at Station 6. Phytane (Phy) and Pristane (Pri) readings can be used to identify petroleum contamination (Farid, 2017; Abdoul-Aziz *et al.*, 2020). The majority of the time, Pristane to Phytane ratios were less than 1, suggesting that N-alkane originated was anthropogenic. With the exception of station 9 during the autumn and station 10 during the summer, the ratio of pristane to phytane was more than 1, indicating that the origin of the n-alkanes were biogenic sources. C17/Pri ratio ranges from (0.171) at Station 6 in winter to (19.308) at Station 3 in winter. C18/Phy ratio ranges from (0.373) at Station 6 in summer to (25.846) at Station 2 in autumn. When C17/pri and C18/phy have values less than 1, it indicates that oil and hydrocarbons are weathering, and when these ratios have a high value, it indicates the presence of oil components (Cripps, 1989; Keshavarzifard *et al.*, 2022; Zhang *et al.*, 2024). As compared to the results of aliphatic with other studies, we find out that our recorded values were exceeded the previous measurements as shown in Table (7).

(Table 1) The concentration of n-alkanes compounds (µg.g^{-1} dw) in soil during summer seasons in the studied locations.

Carbon numbers	station (1)	station (2)	station (3)	station (4)	station (5)	station (6)	station (7)	station (8)	station (9)	station (10)	station (11)
C-9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-11	ND	ND	ND	ND	ND	ND	ND	ND	1.03	1.02	ND
C-12	**ND**	ND	ND	ND	ND	ND	ND	ND	1.23	1.1	ND
C-13	0.03	ND	ND	ND	1.23	ND	1.3	ND	1.34	1.32	1.62
C1-14	0.08	ND	ND	ND	2.36	1.453	1.06	ND	2.35	1.52	1.23
C-15	0.06	1.53	2.13	1.23	3.2	1.25	1.23	2.35	3.56	4.23	2.58
C-16	5.51	2.16	2.63	2.33	2.56	9.304	3.436	5.771	2.759	7.995	4.883
C-17	2.23	3.31	2.53	2.3	3.2	1.532	1.894	3.411	3.581	1.833	1.58
Pr	1.23	2.56	1.25	2.1	4.26	1.981	1.674	2.592	2.83	2.749	1.53
C-18	3.068	9.39	1.727	2.242	3.063	3.796	4.837	9.193	3.121	5.245	2.478
Ph	5.181	4.632	4.161	2.106	6.982	10.189	1.711	2.823	2.201	1.847	1.694
C-19	3.25	2.422	2.519	1.572	2.79	2.067	2.706	4.654	2.238	3.35	1.783
C-20	7.45	1.603	3.545	1.855	4.296	3.135	3.651	6.896	2.562	6.243	4.565
C-21	1.798	4.816	3.931	3.116	5.825	4.22	5.257	10.006	4.387	1.717	4.181
C-22	5.589	3.666	3.599	7.046	4.687	4.769	11.433	22.069	2.184	4.423	1.838
C-23	2.297	3.332	1.939	3.065	2.197	4.567	2.422	5.514	3.706	12.115	1.792
C-24	4.151	8.026	3.291	2.376	2.096	9.784	2.063	8.281	7.677	5.224	7.382
C-25	2.049	23.811	10.155	7.714	11.48	10.387	11.907	25.61	10.564	21.378	9.205
C-26	4.432	18.847	5.552	4.238	8.08	19.905	5.434	15.529	6.006	12.395	4.764
C-27	12.251	31.059	12.4	22.548	28.834	44.567	16.347	29.556	23.31	29.928	14.047
C-28	4.555	46.675	3.529	3.956	5.747	29.6	11.705	30.906	15.071	10.608	2.639
C-29	11.27	54.685	11.643	13.364	27.04	45.584	17.247	28.002	20.779	38.365	8.661
C-30	14.404	50.234	3.758	3.03	5.349	8.45	18.283	9.453	19.47	8.098	12.323
C-31	6.342	16.301	9.333	5.745	9.77	20.657	11.007	23.602	6.483	23.555	5.688
C-32	12.639	12.269	19.459	11.896	8.723	27.551	12.226	16.232	9.753	6.616	4.366
C-33	4.679	32.33	3.495	4.323	5.343	14.057	8.098	14.762	3.432	10.554	2.323
C-34	8.536	18.344	9.457	9.286	11.378	21.091	5.008	5.839	4.049	24.851	2.2
C-35	4.21	14.847	10.853	6.478	12.271	7.595	4.862	13.618	2.26	11.669	2.16
C-36	3.25	5.665	2.637	2.307	3.261	2.789	3.288	6.598	2.38	17.157	2.317
C-37	2.87	4.36	2.32	1.23	2.58	3.899	1.53	6.551	1.42	12.497	1.28
C-38	2.1	3.21	1.56	1.03	2.42	-	1.42	5.27	1.03	9.75	1.06
C-39	1.23	-	-	-	-	-	-	-	-	1.53	-
C-40	1.52	-	-	-	-	-	-	-	**-**	**1.03**	**-**
Total	**138.261**	**380.084**	**126.992**	**128.483**	**188.602**	**314.179**	**173.036**	**315.088**	**172.763**	**298.762**	**112.169**
Pri/phy	0.237	0.553	0.3	0.997	0.61	0.194	0.978	0.918	1.286	1.488	0.903
Cpi	0.706	0.507	0.577	1.409	1.88	0.51	0.496	0.532	0.504	1.449	0.507
C17/pri	1.813	1.293	2.024	1.095	0.751	0.773	1.131	1.316	1.265	0.667	1.033
C18/phy	0.592	2.027	0.415	1.065	0.439	0.373	2.827	3.256	1.418	2.84	1.463

(Table 2) The concentration of n-alkanes compounds (µg.g^{-1} dw) in soil during autumn seasons in the studied locations.

Carbon numbers	station (1)	station (2)	station (3)	station (4)	station (5)	station (6)	station (7)	station (8)	station (9)	station (10)	station (11)
C-9	-	-	-	-	-	-	-	-	-	-	-
C-10	-	-	-	-	-	-	-	-	-	-	-
C-11	1.11	0.78	-	-	-	-	-	-	0.09	1.09	0.743
C-12	0.98	0.97	-	-	-	-	-	-	2.34	1.742	0.553
C-13	1.25	2.13	1.23	1.52	-	0.93	2.464	0.542	3.622	1.534	0.654
C1-14	14.381	12.814	6.023	5.302		2.495	5.57	2.016	5.389	5.143	1.237
C-15	2.35	2.326	1.458	1.268	3.561	1.281	3.813	1.519	1.809	3.462	1.842
C-16	24.776	35.402	21.612	15.697	13.733	19.249	27.341	20.102	26.074	16.666	11.365
C-17	2.888	13.928	2.543	3.035	1.633	2.089	9.238	2.832	3.877	1.83	1.658
Pr	3.07	2.254	2.229	4.203	1.63	3.569	7.387	2.767	2.424	2.598	2.054
C-18	53.818	59.574	17.774	26.823	24.914	28.852	24.264	35.468	34.376	24.829	13.38
Ph	3.373	2.305	2.57	14.573	2.705	5.338	19.254	9.883	10.074	2.829	6.669
C-19	2.527	2.216	1.983	1.625	1.695	3.132	6.495	5.187	4.717	2.743	2.819
C-20	17.008	1.835	11.438	8.367	7.853	2.909	8.23	5.459	3.293	8.434	3.919
C-21	2.944	2.797	2.271	3.497	2.443	4.384	9.726	2.048	4.881	2.178	6.334
C-22	9.324	13.159	6.685	3.36	3.61	3.326	2.577	4.711	9.11	4.739	3.703
C-23	2.152	2.602	2.15	1.885	2.821	3.624	4.138	4.069	3.757	2.498	3.944
C-24	7.473	5.271	2.997	2.432	2.21	2.732	3.839	2.515	3.749	2.79	4.391
C-25	6.97	2.977	5.65	3.162	2.008	5.439	19.839	5.077	2.263	5.177	4.461
C-26	4.453	6.817	3.021	4.207	3.642	8.403	9.357	9.271	2.552	4.873	10.701
C-27	58.63	19.468	62.88	30.133	39.858	65.802	40.645	41.359	29.568	52.16	41.92
C-28	9.766	8.592	27.324	6.045	2.537	21.076	17.674	5.925	2.41	5.006	17.523
C-29	36.747	3.454	24.791	7.265	11.838	27.783	30.676	22.391	10.11	4.697	18.061
C-30	27.14	6.951	27.595	4.451	7.779	5.946	29.431	22.495	5.086	4.569	5.034
C-31	13.163	76.804	16.095	2.187	2.32	12.402	14.548	9.224	12.639	2.731	18.597
C-32	2.769	7.236	6.072	2.419	2.332	6.961	18.963	6.679	2.838	3.065	6.075
C-33	4.415	2.107	8.325	3.581	6.83	6.944	8.238	15.92	7.14	3.225	8.152
C-34	1.23	3.511	4.172	2.531	3.54	15.429	13.488	9.122	6.281	2.542	4.537
C-35	0.97	2.362	2.823	2.928	3.373	4.32	4.897	9.119	2.372	2.31	2.408
C-36	0.14	2.584	2.282	1.46	2.229	2.532	3.52	7.621	4.283	2.091	2.721
C-37	4.235	3.206	5.859	2.56	-	2.457	2.423	6.54	2.391	1.25	2.531
C-38	3.25	2.73	3.55	2.554	-	1.248	2.18	4.23	1.246	1.223	1.743
C-39	2.1	2.906	5.072	0.781	-	0.73	1.78	4.1	1.22	0.954	1.425
C-40	1.43	0.11	0.97	4.741	-	0.63	2.076	3.25	0.953	0.764	1.263
Total	326.832	312.178	289.444	174.592	157.094	272.012	354.071	281.441	212.934	181.742	212.417
Pri/phy	0.91	0.978	0.867	0.288	0.603	0.669	0.384	0.28	0.241	0.918	0.308
Cpi	0.801	0.836	1.011	0.724	1.054	1.16	0.943	0.936	0.822	0.993	1.311
C17/pri	0.941	6.179	1.141	0.722	1.002	0.585	1.251	1.023	1.599	0.704	0.807
C18/phy	15.956	25.846	6.916	1.841	9.21	5.405	1.26	3.589	3.412	8.777	2.006

(Table 3) The concentration of n-alkanes compounds (µg.g^{-1} dw) in soil during winter seasons in the studied locations.

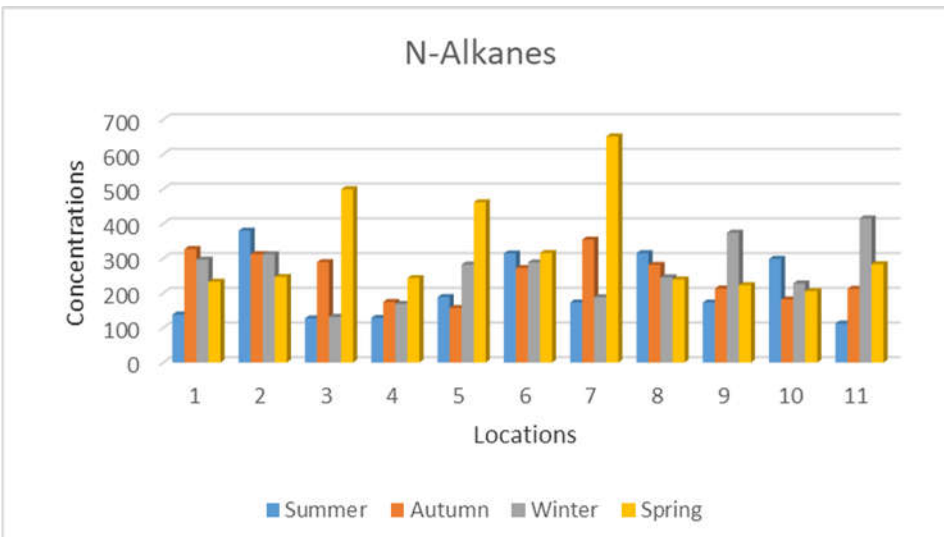
Carbon numbers	station (1)	station (2)	station (3)	station (4)	station (5)	station (6)	station (7)	station (8)	station (9)	station (10)	station (11)
C-9											
C-10											
C-11	-	-	-	-	-	-	-	-	-	-	-
C-12	-	-	-	-	-	-	-	-	-	-	-
C-13	-	2.42	1.1	-	-	1.58	-	2.53	-	1.93	-
C1-14	1.422	2.1	1.228	1.625	3.567	8.623	2.619	2.18	1.044	2.18	1.105
C-15	5.297	5.32	15.92	7.048	1.605	5.622	9.07	3.62	5.04	2.53	5.008
C-16	11.093	7.767	11.417	9.32	13.024	7.319	10.425	8.303	8.08	7.589	7.548
C-17	1.517	9.44	63.792	8.452	6.651	1.301	1.801	9.137	7.579	3.963	6.83
Pr	2.557	1.722	3.304	1.703	1.319	7.599	1.167	1.803	1.622	8.691	1.159
C-18	11.222	9.292	11.786	8.482	12.271	8.826	11.903	9.021	7.937	9.792	6.455
Ph	3.202	2.869	4.31	2.2	4.446	3.103	5.501	2.502	2.082	3.809	1.631
C-19	1.332	1.583	4.581	1.53	2.793	2.49	8.79	6.674	1.351	2.579	7.051
C-20	10.826	9.431	10.218	6.565	10.682	9.935	17.221	7.395	5.806	8.14	6.177
C-21	1.767	2.197	4.628	2.52	3.12	3.962	9.213	8.143	2.363	2.129	2.027
C-22	8.196	8.071	10.569	4.877	10.576	10.138	17.612	5.677	5.377	7.233	7.426
C-23	4.418	5.133	8.678	2.906	8.605	7.71	21.528	3.539	4.155	4.461	6.128
C-24	9.57	5.844	8.992	3.646	8.391	7.749	17.866	3.779	5.16	4.35	7.042
C-25	14.1	4.908	6.822	3.749	8.343	5.441	46.812	11.754	5.988	10.953	5.987
C-26	15.19	11.359	19.412	8.212	19.915	19.918	60.255	4.315	6.343	3.858	16.503
C-27	17.657	17.086	34.483	16.432	32.707	23.985	64.433	16.335	25.665	12.251	22.386
C-28	15.414	14.988	32.382	11.488	29.496	23.324	49.419	8.377	23.136	10.247	26.35
C-29	20.587	25.105	38.274	18.308	109.232	31.533	55.373	23.741	22.613	14.084	27.292
C-30	9.959	20.133	35.755	11.722	26.972	21.634	45.252	11.625	17.312	10.383	24.439
C-31	19.498	23.021	36.391	36.46	54.994	28.634	51.672	27.243	13.397	16.861	26.502
C-32	14.474	4.359	35.086	14.648	27.737	22.421	48.206	10.051	18.494	13.721	22.994
C-33	6.132	9.233	17.984	26.841	11.677	12.028	25.578	15.916	9.621	6.086	12.409
C-34	7.599	12.988	15.944	9.67	21.805	9.317	22.363	10.836	11.978	14.336	17.407
C-35	1.165	9.19	12.691	5.014	11.243	11.453	30.834	11.968	4.469	5.87	3.758
C-36	5.999	10.029	22.329	10.608	11.811	11.496	7.805	7.577	2.84	3.156	7.748
C-37	9.353	3.601	11.6	5.225	3.702	3.02	4.471	1.826	1.019	9.334	1.692
C-38	1.527	2.088	15.505	2.21	3.582	2.304	2.513	1.02	1.25	2.19	1.109
C-39	1.685	2.47	2.436	1.88	1.37	1.566	1.631	1.23	1.339	1.316	1.03
C-40	-	2.623	1.63	-	-	1.32	-	1.11	-	1.32	-
Total	232.758	246.37	499.247	243.341	461.636	315.351	651.333	239.227	223.06	205.342	283.193
Pri/phy	0.799	0.6	0.767	0.774	0.297	2.449	0.212	0.721	0.779	2.282	0.711
Cpi	0.853	0.997	1.117	1.323	1.281	0.854	1.057	1.574	0.911	0.958	0.841
C17/pri	0.593	5.482	19.308	4.963	5.042	0.171	1.543	5.068	4.673	0.456	5.893
C18/phy	3.505	3.239	2.735	3.855	2.76	2.844	2.164	3.606	3.812	2.571	3.958

(Table 4) The concentration of n-alkanes compounds (µg.g^{-1} dw) in soil during spring seasons in the studied locations.

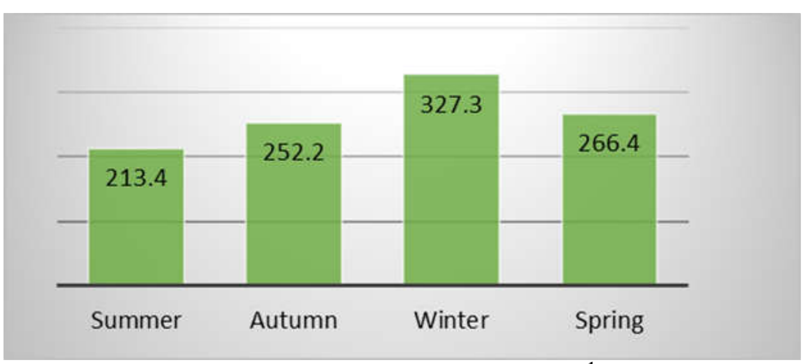
Carbon numbers	station (1)	station (2)	station (3)	station (4)	station (5)	station (6)	station (7)	station (8)	station (9)	station (10)	station (11)
C-9	-	-	-	-	-	-	-	-	-	-	-
C-10	-	-	-	-	-	-	-	-	-	-	-
C-11	-	-	-	-	-	-	-	-	-	-	-
C-12	-	-	-	-	-	-	-	-	-	-	-
C-13	-	-	-	-	-	-	-	-	-	-	-
C1-14	-	-	-	-	-	-	-	-	-	-	-
C-15	-	-	-	-	-	-	-	-	-	-	-
C-16	3.982	10.908	1.75	1.494	6.57	6.454	10.094	6.137	17.417	6.412	13.342
C-17	2.31	1.904	2.1	1.32	4.23	3.25	6.25	1.68	5.135	5.23	2.054
Pr	1.25	2.78	1.2	0.32	1.23	1.521	1.9	1.608	1.536	1.834	1.49
C-18	15.259	23.235	7.024	7.808	16.542	14.968	12.111	20.132	26.813	12.654	25.055
Ph	4.522	7.694	1.835	3.275	5.495	5.925	3.293	3.364	9.313	4.614	9.038
C-19	3.417	3.338	2.1	3.642	4.497	5.463	2.281	2.066	6.307	4.234	5.874
C-20	19.569	23.345	9.473	10.418	19.649	18.075	10.8	20.568	26.859	13.206	26.817
C-21	3.438	2.162	2.11	2.28	2.863	4.419	3.581	2.245	5.023	2.997	5.547
C-22	15.919	18.937	7.827	9.049	17.165	17.433	7.842	15.242	21.57	11.165	23.71
C-23	3.48	5.499	2.082	5.707	6.095	9.883	3.838	2.99	4.41	6.544	10.207
C-24	2.663	3.083	17.899	2.432	3.138	10.582	4.293	50.757	2.892	3.042	4.113
C-25	14.683	4.586	2.834	12.47	4.826	12.694	3.357	6.208	5.549	13.764	20.064
C-26	32.746	46.239	12.278	4.174	41.747	40.946	6.155	32.891	46.545	6.04	57.056
C-27	16.824	16.715	6.17	14.031	19.506	19.912	14.777	6.328	18.856	21.016	25.11
C-28	25.809	31.97	9.435	11.034	27.219	26.333	12.122	19.38	32.269	16.11	41.769
C-29	20.413	15.256	7.429	17.266	19.878	16.832	14.299	7.645	23.098	20.264	23.664
C-30	21.889	26.862	7.561	6.72	20.772	20.027	10.907	12.511	29.965	15.81	35.066
C-31	17.125	13.164	5.186	13.888	16.742	11.525	18.575	9.277	27.427	15.891	20.433
C-32	18.271	18.746	5.855	12.365	19.181	14.794	12.422	7.402	23.191	4.457	30.387
C-33	16.413	12.695	4.913	13.848	5.52	11.958	12.358	5.485	19.566	7.322	6.99
C-34	10.692	5.142	3.659	5.829	3.151	4.792	7.491	4.32	5.546	11.202	8.444
C-35	3.658	3.905	3.21	4.156	4.998	2.523	3.273	2.753	3.922	8.205	4.421
C-36	8.819	5.295	2.21	2.214	8.86	5.831	2.903	2.883	9.174	11.402	11.84
C-37	6.152	2.25	3.1	1.41	2.628	2.31	1.23	1.54	1.54	4.481	2.43
C-38	4.31	3.51	1.2	1.1	-	-	1.05	-	-	-	-
C-39	3.21	2.61	0.9	0.83	-	-	1.02	-	-	-	-
C-40	-	-	-	-	-	-	-	-	-	-	-
Total	296.823	311.83	131.34	169.08	282.502	288.45	188.222	245.412	373.923	227.896	414.921
Pri/phy	0.276	0.361	0.654	0.098	0.224	0.257	0.577	0.478	0.165	0.397	0.165
Cpi	0.618	0.387	0.489	1.217	0.499	0.559	0.864	0.251	0.499	0.986	0.457
C17/pri	1.848	0.685	1.75	4.125	3.439	2.137	3.289	1.045	3.343	2.852	1.379
C18/phy	3.374	3.02	3.828	2.384	3.01	2.526	3.678	5.985	2.879	2.743	2.772

(Table 5) Seasonal variations of n-Alkanes (µg.g^{-1}) with mean at the selected station.

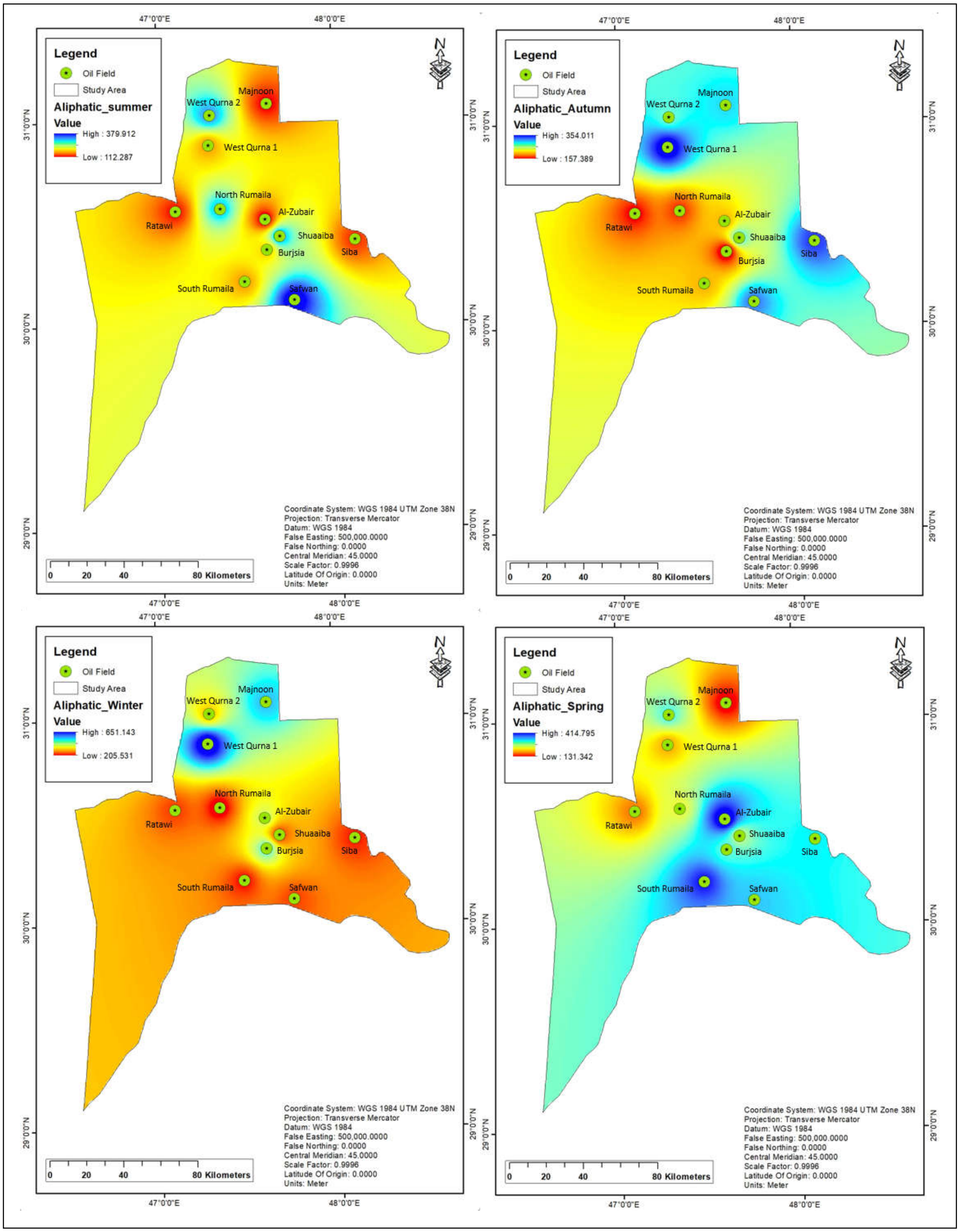
Locations	Summer	Autumn	Winter	Spring	Sp. mean
1	**138.261**	326.832	232.758	296.823	248.669
2	**380.084**	312.178	246.37	311.83	312.616
3	**126.992**	289.444	499.247	131.34	261.756
4	**128.483**	174.592	243.341	169.08	178.874
5	**188.602**	157.094	461.636	282.502	272.459
6	**314.179**	272.012	315.351	288.45	297.498
7	**173.036**	354.071	651.333	188.222	341.666
8	**315.088**	281.441	239.227	245.412	270.292
9	**172.763**	212.934	223.06	373.923	245.670
10	**298.762**	181.742	205.342	227.896	228.436
11	**112.169**	212.417	283.193	414.921	255.675
S. Mean	213.493	252.251	327.351	266.400	264.873



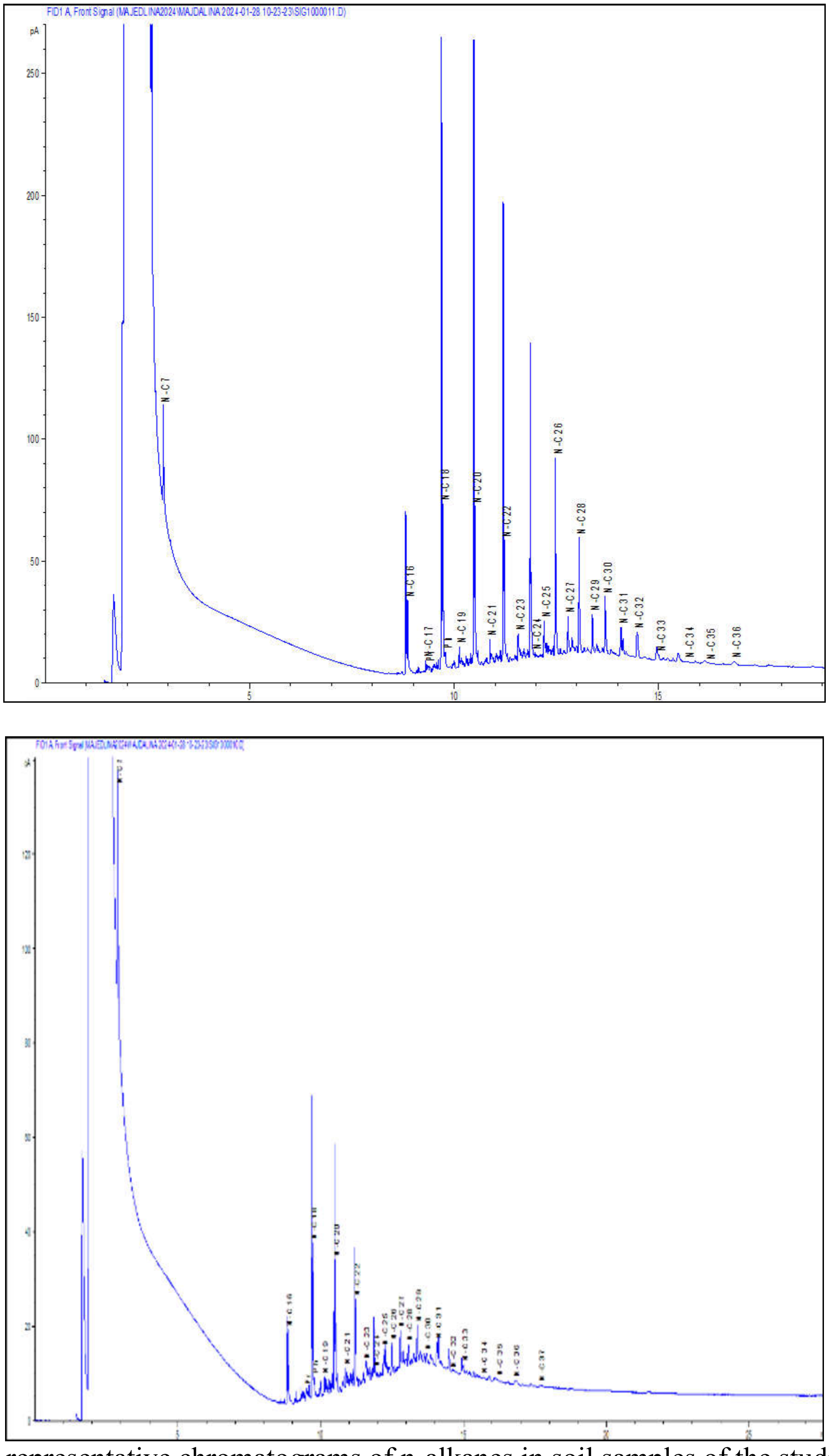
(Figure 2) Seasonal and mean concentrations of n-alkane (µg.g^{-1}) at the selected stations.



(Figure 3) Seasonal variations of n-alkanes (µg.g^{-1}) at oil field.



(Figure 4) GIS maps of n-alkane in the studied location.



(Figure 5) A representative chromatograms of n-alkanes in soil samples of the studied locations during different seasons.

(Table 6) Seasonal variation of TOC% and grain size in West Qurna2 oil field.

Station	TOC				Grain size		
	Summer	Autumn	Winter	Spring	Clay%	Silt%	Sand%
1	8.12	11.86	18.26	13.46	30.49	29.2	40.31
2	0.46	6.24	10.78	2.76	15.31	18.36	66.33
3	3.8	8.41	26.44	10.8	19.35	68.86	11.79
4	8.55	9.8	10.29	2.83	13.29	18.36	68.35
5	1.45	2.1	7.41	7.13	15.31	12.3	72.39
6	5.39	6.36	8.7	20.93	27.43	62.8	9.77
7	10.12	11.35	15.23	22.2	15.31	12.3	72.39
8	4	6.27	10.54	12.5	11.27	14.32	74.41
9	2.46	4.75	6.4	9.2	13.29	22.4	64.31
10	9.79	12.93	14.88	5.6	17.33	40.58	42.09
11	3.93	5.54	16.84	9.2	13.29	8.26	78.45

(Table 7) Showing the comparing of the soil n- alkane ($\mu g.g^{-1}dw$) in the current study with previous studies.

Researcher name	Study area	N- alkane (µg g-1dw)
Douabul *et al.* (2012)	Basrah city	9.2 - 42.9
Al-Saad *et al.* (2015)	Basrah city	3.575 - 21.266
Karem (2016)	West Qurna-2 Oil Field	5.392 - 24.240
Kadhim (2019	West Qurna-1 Oil Field	5.868 - 17.788
Al-Halfy *et al.* 2021	Rumaila Oil Field	99.99 - 100
Saleem (2022)	Basrah city	10.317 - 410.812
Current Study	selected station	112.169 - 651.333

Conclusion:

In the soil of the Basrah province, the survey established baseline data regarding the distribution and concentrations of aliphatic hydrocarbons. The data can be used for the environmental influence assessment in future studies. The highest mean concentrations of total n-alkanes in soil (341.666 µg/g dry weight) are recorded at Station 7, while the lowest mean concentrations in soil (178.874 µg/g dry weight) are recorded at Station 4. Higher concentrations of total aliphatic hydrocarbons were found at oil fields connected to the release of petroleum waste (e.g., Al-Zuber, Safwan, west Qurna2, west Qurna1, Shuaaba. It is possible to determine that the majority of the n-alkanes in the soil of the oil field in Basrah City came from both biogenic and anthropogenic sources based on the distribution patterns and diagnostic indices.

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