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Evaluation of the Sources and Distribution of n-Alkanes in a Sediment Core from Khor Al-Zubair, Northwestern Arabian Gulf

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ABSTRACT

Five sediment core samples were collected from various locations in Khor Al-Zubair, in the northwestern part of the Arabian Gulf, to evaluate the sources and distribution of n-alkane concentrations in the study area. Hydrocarbon compounds were extracted from the sediment samples and analyzed using gas chromatography. A broad range of alkanes, from C_8 to C_{40}, was identified across the sampling locations. The concentration of n-alkanes varied widely, ranging from a low of 0.1828 µg/g at the third station (40–45 cm depth) to a relatively high concentration of 15.4762 µg/g at the fifth station (45–50 cm depth). In several stations and depths, the Carbon Preference Index (CPI) values were low, indicating potential petroleum pollution. CPI was calculated to determine the origin of the hydrocarbons found in the sediments. The C_{17}/pristane (C_{17}/Pri) ratio was lowest at the first station (0.50609) and highest at the second station (2.6675), while the C_{18}/phytane (C_{18}/Phy) ratio was highest at the first station (3.4841) and lowest at the fifth station. These ratios serve as useful indicators for distinguishing between biogenic and petrogenic sources of hydrocarbons. Lower molecular weight alkanes (C_{10}–C_{15}) are more prone to evaporation and microbial degradation, which explains their typically low concentrations. In contrast, higher molecular weight alkanes (C_{33}–C_{36}), being more resistant to degradation, tend to accumulate in the water column and sediments. Phytane is generally associated with petroleum sources, while pristane is often linked to zooplankton. In aquatic systems, odd-numbered alkanes such as C_{15}, C_{17}, and C_{19} are commonly derived from phytoplankton and algal sources, whereas C_{25}, C_{27}, C_{29}, and C_{31} are recognized as biomarkers of terrestrial plant material. Overall, the presence of hydrocarbons in the form of n-alkanes in this region is attributed to both anthropogenic activities—including vehicle emissions, oil spills, and industrial discharges—and natural sources, such as marine organisms, plankton, and terrestrial vegetation.

INTRODUCTION

Pollution is one of the most pressing environmental challenges facing humanity today. It occurs when substances are released into the environment in ways or quantities that ecosystems cannot efficiently absorb or neutralize, leading to harmful ecological impacts **(Harrison, 1996)**. A major contributor to this problem is the discharge of industrial waste, plant effluents, atmospheric pollutants, and vehicle emissions, all of which introduce hydrocarbons into aquatic systems **(Grmashaet *et al.*, 2020)**.

Among these pollutants, n-alkanes—a subgroup of aliphatic hydrocarbons—are of particular interest. They are produced by a wide range of organisms, but their profiles vary depending on their source. For example, the n-alkane composition in aquatic organisms differs significantly from that found in the surface waxes of higher terrestrial plants. Additionally, petroleum-derived hydrocarbons, often introduced through ship traffic, oil transportation, and refining activities, represent another major source of n-alkanes in aquatic environments **(Wu *et al.*, 2001)**.

Aliphatic hydrocarbons, especially n-alkanes, enter the environment through both anthropogenic activities—such as vehicle exhaust, oil spills, and industrial emissions—and natural sources, including marine organisms, plankton, and terrestrial vegetation. In sedimentary environments, n-alkanes serve as sensitive markers for identifying the sources of aliphatic hydrocarbons. Although they constitute only a small fraction of total hydrocarbons, n-alkanes provide valuable information about the origin and maturity of hydrocarbon inputs **(Wang *et al.*, 2018)**.

Typically found in marine sediments, n-alkanes ranging in carbon chain length from n-C14 to n-C34 are considered source-specific and resistant to degradation, making them reliable molecular biomarkers for environmental monitoring **(Zhao *et al.*, 2022)**.

The aim of this study was to evaluate the concentrations and sources of n-alkanes in the sediments of the study area, with the goal of distinguishing between natural and anthropogenic inputs and understanding the extent of hydrocarbon pollution.

MATERIALS AND METHODS

Study area

Khor Al-Zubair is a significant seawater body in Iraq, located in the northwestern part of the Arabian Gulf. It holds considerable national importance due to its involvement in various economic and industrial activities, including fishing and oil transport **(Lafta *et al.*, 2019)**. Geologically, Khor Al-Zubair is primarily composed of Quaternary sediments such as clay, silt, and sand, which are associated with different geological structures. It is also recognized as the largest and most prominent lagoon in the northern Arabian Gulf **(Hazza & Jassim, 2024)**.

The total extent of Khor Al-Zubair spans approximately 60 km, with navigation channels ranging in width from 10 to 20 meters. The northern section features numerous shallow tidal lakes, characterized by irregular widths and a complex geometry that often resembles the fronds of a palm tree **(Lafta *et al.*, 2019)**. This geographical complexity is illustrated in Fig. (1) and Table (1).

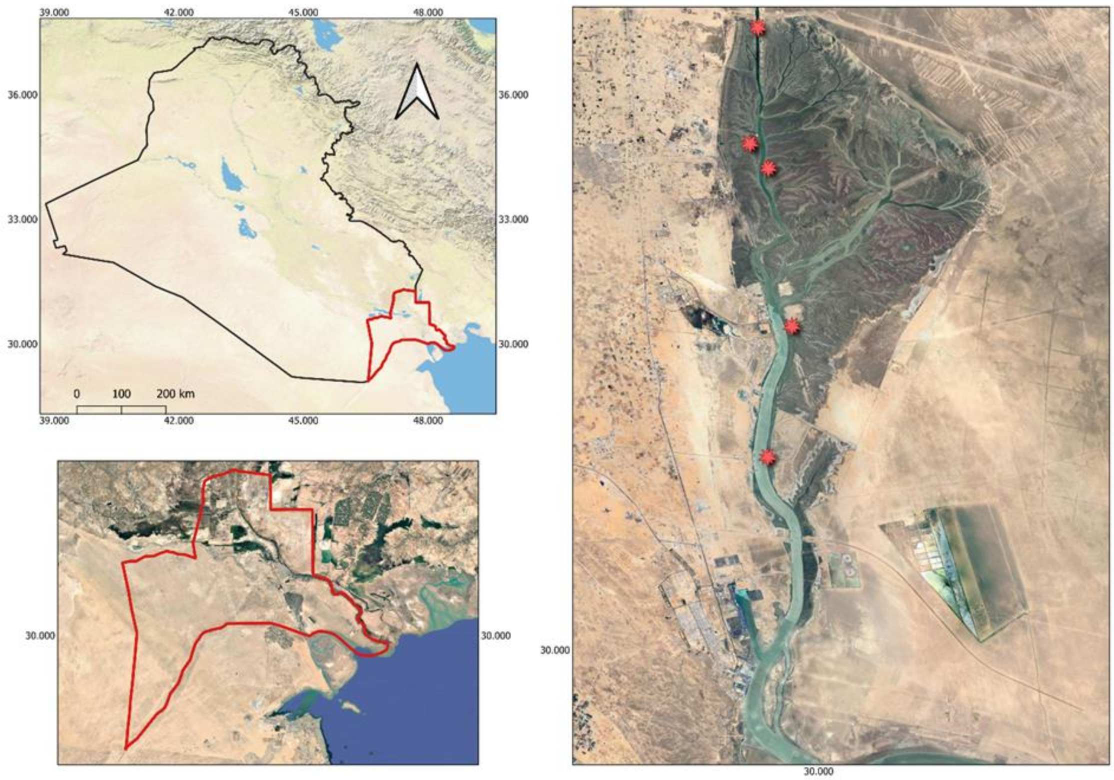


Fig. 1. Location of study area, Southern Iraq

Table 1. Study stations coordinated

Station	Latitude	Longitude
1	**30° 20'04.5**	**47° 48'44.1**
2	**30° 16'57.4**	**47° 50'09.6**
3	**30° 14'22.3**	**47° 52'08.6**
4	**30° 11'57.8**	**47° 53'20.1**
5	**30° 09'31.2**	**47° 54'08.6**

Samples analysis

Sediment samples were dried in an oven at 50 °C for approximately three days, finely ground using an electric mortar, and sieved through a 63 µm mesh. The processed samples were then stored in glass containers until analysis. For hydrocarbon extraction, 50 g of the sieved sediment was placed in a cellulose thimble and subjected to Soxhlet intermittent extraction following the method of **(Goutx & Saliot, 1980; Al-Hejueje, 2014)** using 120 ml of a mixed solvent (methanol:benzene, 1:1 v/v) for 48 hours at a temperature not exceeding 40°C.

The combined extracts underwent saponification for 2 hours by adding 15ml of 4 M KOH in methanol (MeOH) at the same temperature, then allowed to cool to room temperature. The unsaponifiable fraction was extracted using 50ml of n-hexane in a separatory funnel. For purification, the extract was passed through a 20 cm glass column packed sequentially with glass wool, 8 g of silica gel (100–200 mesh), 4 g of aluminum oxide (Al_2O_3, 100–200 mesh), and 4 g of anhydrous sodium sulfate (Na_2SO_4) on the top. The aliphatic fraction, containing the n-alkanes, was eluted using hexane.

The n-alkanes (C_8–C_{40}) were analyzed using a GC-MS system (Agilent 7890B gas chromatograph coupled with an Agilent 5977A mass spectrometer). The oven temperature was programmed from an initial temperature of 40 °C, increasing at a rate of 10 °C/min to a final temperature of 310 °C. The injector was operated in split mode (75:1) at 260 °C. The GC was run under constant flow conditions: pressure of 7.07 psi, total flow of 79 mL/min, column flow of 1 mL/min, and purge flow of 3 mL/min.
Mass spectrometer conditions were as follows: ion source temperature of 250 °C, quadrupole temperature of 150 °C, and interface temperature of 280 °C. The solvent cut time was set at 4.00 minutes, and data acquisition was performed between 4.00 and 40.00 minutes. Identification of individual n-alkanes was achieved by comparing retention times and mass spectra with authentic standards and entries from the NIST mass spectral library. Quantification was performed using external calibration with n-alkane standards ranging from C_8 to C_{40}.

RESULTS

In our study, we measured the concentrations of natural n-alkanes from five stations within the study area (Tables 2–6), and the GC chromatograms for each station are presented in Figs. (2 and 3). A total of 36 compounds were identified, including pristane and phytane. The overall concentrations of these compounds are summarized in Table (7) and visualized in Fig, 4.

Among all stations, Station 5 exhibited the highest level of n-alkane contamination, with a maximum concentration of 15.82 µg/g dw recorded at the 25–30 cm depth. The lowest concentration at this station was 5.07 µg/g dw, observed at a depth of 10–15cm.

The station-specific findings are as follows:

- Station 1: The highest concentration was 14.51 µg/g dw at 15–20 cm, while the lowest was 0.54 µg/g dw at 40–45 cm.
- Station 2: The lowest concentration was 1.13 µg/g dw at 10–15 cm, and the highest was 2.03 µg/g dw at 40–45 cm.
- Station 3: The highest value was 2.09 µg/g dw at 25–30 cm, with the lowest at 0.18 µg/g dw at 40–45 cm.
- Station 4: The peak concentration of 8.80 µg/g dw was found at 0–5 cm, while the minimum was 2.23 µg/g dw at 25–30 cm.

These results indicate spatial and depth-related variability in n-alkane concentrations across the study area, with the highest accumulation observed in Station 5.

Table 2. Concentration of N-Alkane (µg/g dw) at station 1

N-alkane Component Name	Core 1									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
n-C8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C10	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C11	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C13	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C14	**0.012961**	**0.0213**	**0.057397**	**0.092308**	**0.065203**	**0.019228**	**0.004977**	**0.00515**	**0**	**0**
n-C15	**0.010744**	**0.0091**	**0.01479**	**0.046693**	**0.016747**	**0.010446**	**0.009153**	**0.00752**	**0.00341**	**0.0062**
n-C16	**0.169994**	**0.1186**	**0.156198**	**0.372819**	**0.157027**	**0.11162**	**0.123797**	**0.0965**	**0.07528**	**0.1051**
n-C17	**0.021357**	**0.0167**	**0.05243**	**0.231345**	**0.047257**	**0.027293**	**0.026298**	**0.00911**	**0.00921**	**0.0083**
Pr	**0.019894**	**0.0261**	**0.07221**	**0.120888**	**0.067244**	**0.034665**	**0.036184**	**0.01679**	**0.0181**	**0.0164**

n-C18	**0.174089**	**0.1122**	**0.167952**	**0.416719**	**0.183008**	**0.14423**	**0.139549**	**0.09017**	**0.0773**	**0.0878**
Ph	**0.062847**	**0.0677**	**0.0625**	**0.233014**	**0.162038**	**0.075784**	**0.065694**	**0.02894**	**0.03007**	**0.0252**
n-C19	**0.081287**	**0.0799**	**0.221311**	**0.243452**	**0.202808**	**0.126296**	**0.074455**	**0.02289**	**0.00898**	**0.0145**
n-C20	**0.158797**	**0.1367**	**0.230117**	**0.515793**	**0.251516**	**0.155466**	**0.139837**	**0.09166**	**0.06202**	**0.0723**
n-C21	**0.046359**	**0.0475**	**0.161533**	**0.458652**	**0.192561**	**0.078409**	**0.040325**	**0.01925**	**0.00379**	**0.0121**
n-C22	**0.128241**	**0.1139**	**0.194934**	**0.475629**	**0.290117**	**0.115274**	**0.082918**	**0.06816**	**0.03449**	**0.0644**
n-C23	**0.07058**	**0.0782**	**0.234828**	**0.644276**	**0.306758**	**0.10272**	**0.041395**	**0.02861**	**0.01287**	**0.0243**
n-C24	**0.068896**	**0.0693**	**0.17314**	**0.498615**	**0.211224**	**0.08219**	**0.039018**	**0.03392**	**0.01731**	**0.0275**
n-C25	**0.13748**	**0.1452**	**0.377925**	**0.986566**	**0.503912**	**0.175114**	**0.071977**	**0.06796**	**0.0162**	**0.0417**
n-C26	**0.125495**	**0.2088**	**0.386595**	**1.420088**	**0.282016**	**0.17444**	**0.06028**	**0.06903**	**0.01035**	**0.059**
n-C27	**0.23539**	**0.2464**	**0.585956**	**0.925231**	**0.769369**	**0.29171**	**0.131783**	**0.17267**	**0.03363**	**0.1167**
n-C28	**0.155676**	**0.1906**	**0.603796**	**1.817593**	**0.748383**	**0.249285**	**0.102142**	**0.11255**	**0.01815**	**0.0883**
n-C29	**0.137406**	**0.1727**	**0.452067**	**1.250601**	**0.588796**	**0.22605**	**0.112556**	**0.12003**	**0.03206**	**0.0927**
n-C30	**0.070848**	**0.0994**	**0.276826**	**0.802792**	**0.442529**	**0.182349**	**0.050041**	**0.05189**	**0.00778**	**0.0422**
n-C31	**0.052379**	**0.0837**	**0.246526**	**0.784942**	**0.351389**	**0.130141**	**0.063695**	**0.06046**	**0.02778**	**0.05007**
n-C32	**0.049222**	**0.0635**	**0.23895**	**1.00916**	**0.309987**	**0.060307**	**0.034395**	**0.029726**	**0.007057**	**0.0142**
n-C33	**0.055424**	**0.0282**	**0.071072**	**0.521706**	**0.103756**	**0.021314**	**0.015255**	**0.044767**	**0.02266**	**0.0318**
n-C34	**0.056249**	**0.0218**	**0.018966**	**0.216422**	**0.011558**	**0.02785**	**0.013136**	**0.014645**	**0.003738**	**0.0069**
n-C35	**0.053196**	**0.0073**	**0.024523**	**0.13757**	**0.020338**	**0.010186**	**0.028467**	**0.00782**	**0**	**0.01303**
n-C36	**0.016699**	**0.0065**	**0.006339**	**0.162224**	**0.016052**	**0.010292**	**0.01758**	**0.00848**	**0.01076**	**0.01724**
n-C37	**0.023038**	**0**	**0.012984**	**0.096346**	**0.030468**	**0**	**0**	**0**	**0**	**0**
n-C38	**0.015**	**0**	**0**	**0.025899**	**0**	**0**	**0**	**0**	**0**	**0**
n-C39	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 3. Concentration of N-Alkane (μg/g dw) at station 2

N-alkane Component Name	Core 2								
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45
n-C8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C10	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C11	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C13	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C14	**0.029253**	**0.034087**	**0.01536**	**0.014967**	**0.040317**	**0.038241**	**0.036379**	**0.073689**	**0.053924**
n-C15	**0.04792**	**0.046992**	**0.019815**	**0.010579**	**0.056775**	**0.018239**	**0.045532**	**0.050142**	**0.032897**
n-C16	**0.194634**	**0.226901**	**0.155203**	**0.147608**	**0.195794**	**0.218312**	**0.204748**	**0.204748**	**0.194501**
n-C17	**0.048384**	**0.054122**	**0.039331**	**0.041818**	**0.051966**	**0.045068**	**0.050971**	**0.06868**	**0.070272**
Pr	**0.058925**	**0.077049**	**0.059084**	**0.020369**	**0.021128**	**0.061677**	**0.060507**	**0.025746**	**0.069553**
n-C18	**0.142491**	**0.127372**	**0.111525**	**0.137651**	**0.11453**	**0.13762**	**0.127878**	**0.134552**	**0.136513**
Ph	**0.080655**	**0.089353**	**0.086918**	**0.105611**	**0.088562**	**0.091472**	**0.077365**	**0.112727**	**0.09299**
n-C19	**0.049563**	**0.040802**	**0.03514**	**0.048551**	**0.030459**	**0.064492**	**0.047665**	**0.042288**	**0.061234**
n-C20	**0.112964**	**0.081409**	**0.078969**	**0.104161**	**0.0762**	**0.099874**	**0.092653**	**0.09595**	**0.102281**
n-C21	**0.029477**	**0.016552**	**0.016651**	**0.023278**	**0.012166**	**0.021333**	**0.020509**	**0.019486**	**0.025026**
n-C22	**0.07292**	**0.046154**	**0.045834**	**0.062763**	**0.041043**	**0.063306**	**0.062348**	**0.060272**	**0.071643**
n-C23	**0.045004**	**0.024913**	**0.02469**	**0.03523**	**0.018078**	**0.037817**	**0.040628**	**0.044557**	**0.048645**
n-C24	**0.041857**	**0.026381**	**0.025515**	**0.033582**	**0.020391**	**0.039052**	**0.043795**	**0.045803**	**0.05065**
n-C25	**0.094446**	**0.049058**	**0.061764**	**0.080909**	**0.049993**	**0.095173**	**0.118716**	**0.127613**	**0.128133**
n-C26	**0.035716**	**0.02842**	**0.02498**	**0.028872**	**0.027447**	**0.04263**	**0.053505**	**0.07793**	**0.057014**
n-C27	**0.117816**	**0.066847**	**0.084914**	**0.102216**	**0.077131**	**0.106177**	**0.133903**	**0.166527**	**0.173476**
n-C28	**0.100451**	**0.04921**	**0.067781**	**0.074774**	**0.053834**	**0.123233**	**0.160864**	**0.131353**	**0.146954**

n-C29	**0.1453**	**0.060639**	**0.074248**	**0.085451**	**0.068571**	**0.145338**	**0.152255**	**0.149661**	**0.15609**
n-C30	**0.074803**	**0.021392**	**0.026723**	**0.028373**	**0.022492**	**0.053274**	**0.091449**	**0.067753**	**0.098706**
n-C31	**0.070401**	**0.033911**	**0.03367**	**0.037419**	**0.035183**	**0.061597**	**0.091965**	**0.088664**	**0.092378**
n-C32	**0.027266**	**0.016253**	**0.016324**	**0.016894**	**0.014613**	**0.021243**	**0.029155**	**0.029726**	**0.036712**
n-C33	**0.009124**	**0.028942**	**0.007663**	**0.034823**	**0.032185**	**0.043947**	**0.02552**	**0.014292**	**0.022775**
n-C34	**0.007682**	**0.007785**	**0.00463**	**0**	**0.005796**	**0.017869**	**0.054671**	**0.028055**	**0.033543**
n-C35	**0**	**0**	**0**	**0**	**0**	**0.01804**	**0.054568**	**0.021745**	**0.040231**
n-C36	**0.02113**	**0.023515**	**0.013496**	**0.026242**	**0.011894**	**0.016324**	**0.034285**	**0.03483**	**0.030263**
n-C37	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C38	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C39	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 4. Concentration of N-Alkane (µg/g dw) at station 3

N-alkane Component Name	Core 3									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
n-C8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C10	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C11	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C13	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C14	**0.02721**	**0.03279**	**0.04919**	**0.04937**	**0.06054**	**0.0421**	**0.04357**	**0**	**0.00537**	**0.06362**
n-C15	**0.01243**	**0.01389**	**0.01601**	**0.01485**	**0.03296**	**0.02347**	**0.02991**	**0.00722**	**0.00361**	**0.04344**
n-C16	**0.10711**	**0.12353**	**0.15745**	**0.13822**	**0.23307**	**0.24978**	**0.25266**	**0.0189**	**0.0256**	**0.26822**
n-C17	**0.02135**	**0.02132**	**0.04171**	**0.02759**	**0.06546**	**0.07176**	**0.07402**	**0.00368**	**0.0048**	**0.06493**

Pr	**0.02761**	**0.02966**	**0.05411**	**0.03669**	**0.0785**	**0.09163**	**0.09846**	**0.00398**	**0.00512**	**0.02796**
n-C18	**0.09242**	**0.11124**	**0.15036**	**0.12145**	**0.16317**	**0.20056**	**0.1788**	**0.01758**	**0.02043**	**0.1484**
Ph	**0.04023**	**0.04504**	**0.10055**	**0.06404**	**0.11582**	**0.1434**	**0.14429**	**0.00569**	**0.00648**	**0.13265**
n-C19	**0.02944**	**0.02147**	**0.06145**	**0.04956**	**0.09077**	**0.05731**	**0.0662**	**0**	**0**	**0.09713**
n-C20	**0.06733**	**0.08084**	**0.10805**	**0.09403**	**0.11434**	**0.13802**	**0.12506**	**0.01022**	**0.0118**	**0.09572**
n-C21	**0.01196**	**0.0181**	**0.02829**	**0.01843**	**0.02845**	**0.03561**	**0.0266**	**0.00451**	**0.00537**	**0.02568**
n-C22	**0.03928**	**0.04813**	**0.06158**	**0.06103**	**0.06151**	**0.08416**	**0.07528**	**0.00488**	**0.00795**	**0.05474**
n-C23	**0.01727**	**0.0243**	**0.03494**	**0.03312**	**0.03695**	**0.04835**	**0.03813**	**0.00418**	**0.00392**	**0.02935**
n-C24	**0.01987**	**0.02769**	**0.03334**	**0.03427**	**0.03763**	**0.04608**	**0.04293**	**0.00512**	**0.00495**	**0.02911**
n-C25	**0.02922**	**0.06602**	**0.07706**	**0.07876**	**0.08679**	**0.11757**	**0.09974**	**0.02811**	**0.00484**	**0.07377**
n-C26	**0.01636**	**0.02678**	**0.02984**	**0.0296**	**0.0347**	**0.04311**	**0.04249**	**0.00535**	**0.00528**	**0.02786**
n-C27	**0.05277**	**0.08116**	**0.08918**	**0.09651**	**0.10492**	**0.14189**	**0.12344**	**0.00837**	**0.00858**	**0.10249**
n-C28	**0.02857**	**0.06067**	**0.06458**	**0.07278**	**0.08097**	**0.10357**	**0.09078**	**0.00533**	**0.00706**	**0.07484**
n-C29	**0.0433**	**0.1253**	**0.09127**	**0.10729**	**0.11447**	**0.13545**	**0.12203**	**0.00744**	**0.00909**	**0.07887**
n-C30	**0.01547**	**0.02465**	**0.02376**	**0.03136**	**0.02864**	**0.02844**	**0.03387**	**0**	**0.0035**	**0.03009**
n-C31	**0.07968**	**0.10063**	**0.08997**	**0.0965**	**0.11177**	**0.11862**	**0.10644**	**0.01296**	**0.0164**	**0.02025**
n-C32	**0.00969**	**0.01154**	**0.01137**	**0.01325**	**0.01475**	**0.01497**	**0.01889**	**0**	**0**	**0.01151**
n-C33	**0.04437**	**0.07285**	**0.06052**	**0.06159**	**0.06932**	**0.07317**	**0.06529**	**0.0237**	**0.00609**	**0.06205**
n-C34	**0.03687**	**0.05024**	**0.04177**	**0.0415**	**0.04458**	**0.04544**	**0.04609**	**0**	**0.00524**	**0.04613**
n-C35	**0**	**0.00603**	**0.01591**	**0.01769**	**0.01395**	**0.02884**	**0.02201**	**0**	**0**	**0.00696**
n-C36	**0.04283**	**0.00766**	**0.00555**	**0.00555**	**0.04502**	**0.00555**	**0.00753**	**0.0064**	**0.01138**	**0.0065**
n-C37	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C38	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C39	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 5. Concentration of N-Alkane (µg/g dw) at station 4

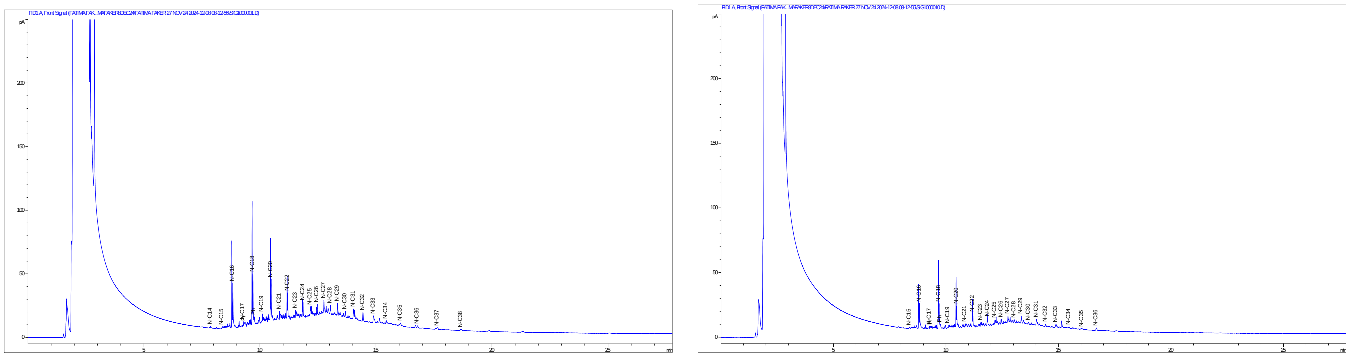
N-alkane Component Name	Core 4									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
n-C8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C10	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C11	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C12	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C13	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C14	**0.18218**	**0**	**0.02878**	**0**	**0**	**0.01006**	**0.03233**	**0.0247**	**0**	**0.01059**
n-C15	**0.22395**	**0.00606**	**0.02155**	**0.0058**	**0.00709**	**0.00974**	**0.02255**	**0.01704**	**0.00467**	**0.01293**
n-C16	**0.73277**	**0.14893**	**0.25107**	**0.16031**	**0.19741**	**0.1736**	**0.27074**	**0.25764**	**0.14051**	**0.22016**
n-C17	**0.40846**	**0.04208**	**0.08834**	**0.07541**	**0.08861**	**0.05282**	**0.08095**	**0.06775**	**0.03797**	**0.05859**
Pr	**0.21432**	**0.03422**	**0.08109**	**0.03128**	**0.05095**	**0.03824**	**0.06537**	**0.05642**	**0.03087**	**0.02824**
n-C18	**0.48766**	**0.18243**	**0.22245**	**0.19641**	**0.24743**	**0.19357**	**0.26366**	**0.25332**	**0.1985**	**0.22589**
Ph	**0.5005**	**0.09893**	**0.12512**	**0.09327**	**0.15137**	**0.10785**	**0.16118**	**0.13607**	**0.08973**	**0.13217**
n-C19	**0.23807**	**0.0549**	**0.07062**	**0.05408**	**0.08359**	**0.05237**	**0.07967**	**0.06689**	**0.0512**	**0.06227**
n-C20	**0.41037**	**0.15553**	**0.17937**	**0.16783**	**0.19892**	**0.14686**	**0.20172**	**0.17762**	**0.16305**	**0.17548**
n-C21	**0.20354**	**0.04312**	**0.06113**	**0.0483**	**0.07092**	**0.04118**	**0.06146**	**0.04906**	**0.048**	**0.04982**
n-C22	**0.26028**	**0.10425**	**0.14357**	**0.12028**	**0.14747**	**0.09936**	**0.14261**	**0.10629**	**0.11262**	**0.12172**
n-C23	**0.29072**	**0.06915**	**0.10281**	**0.0787**	**0.10383**	**0.06174**	**0.09802**	**0.06445**	**0.07173**	**0.07902**
n-C24	**0.21205**	**0.06283**	**0.09257**	**0.0708**	**0.08963**	**0.05705**	**0.08665**	**0.05954**	**0.06594**	**0.06986**
n-C25	**0.47562**	**0.10919**	**0.23978**	**0.18009**	**0.22413**	**0.14561**	**0.15662**	**0.14322**	**0.15929**	**0.18093**
n-C26	**0.21152**	**0.09603**	**0.0971**	**0.06625**	**0.1496**	**0.0568**	**0.09961**	**0.05972**	**0.09735**	**0.1142**
n-C27	**0.57032**	**0.20182**	**0.31095**	**0.2202**	**0.27267**	**0.19314**	**0.2925**	**0.22837**	**0.20592**	**0.23549**
n-C28	**0.6259**	**0.17135**	**0.31507**	**0.18733**	**0.26864**	**0.15977**	**0.29071**	**0.158**	**0.1706**	**0.19913**

n-C29	**0.61992**	**0.23101**	**0.41954**	**0.25718**	**0.36552**	**0.17627**	**0.33075**	**0.16515**	**0.22721**	**0.20672**
n-C30	**0.43716**	**0.09155**	**0.21199**	**0.10472**	**0.18045**	**0.08567**	**0.22712**	**0.06015**	**0.08725**	**0.10166**
n-C31	**0.52785**	**0.13977**	**0.27503**	**0.14145**	**0.09635**	**0.12649**	**0.2684**	**0.05953**	**0.14451**	**0.07545**
n-C32	**0.36694**	**0.02986**	**0.20091**	**0.0304**	**0.11644**	**0.02904**	**0.21025**	**0.04355**	**0.02954**	**0.03646**
n-C33	**0.354**	**0.02302**	**0.09121**	**0.10578**	**0.24697**	**0.09602**	**0.13701**	**0.02773**	**0.11958**	**0.13669**
n-C34	**0.18298**	**0.04863**	**0.11263**	**0.04026**	**0.08804**	**0.04091**	**0.3022**	**0.06183**	**0.06084**	**0.06691**
n-C35	**0.04685**	**0.05165**	**0.06804**	**0.03954**	**0.04362**	**0.03563**	**0.3165**	**0.03971**	**0.03477**	**0.07473**
n-C36	**0.011**	**0.07286**	**0.01288**	**0.05643**	**0.00678**	**0.0429**	**0.07671**	**0.05582**	**0.05643**	**0.00961**
n-C37	**0.00627**	**0**	**0**	**0**	**0**	**0**	**0.01663**	**0**	**0**	**0.01765**
n-C38	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C39	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

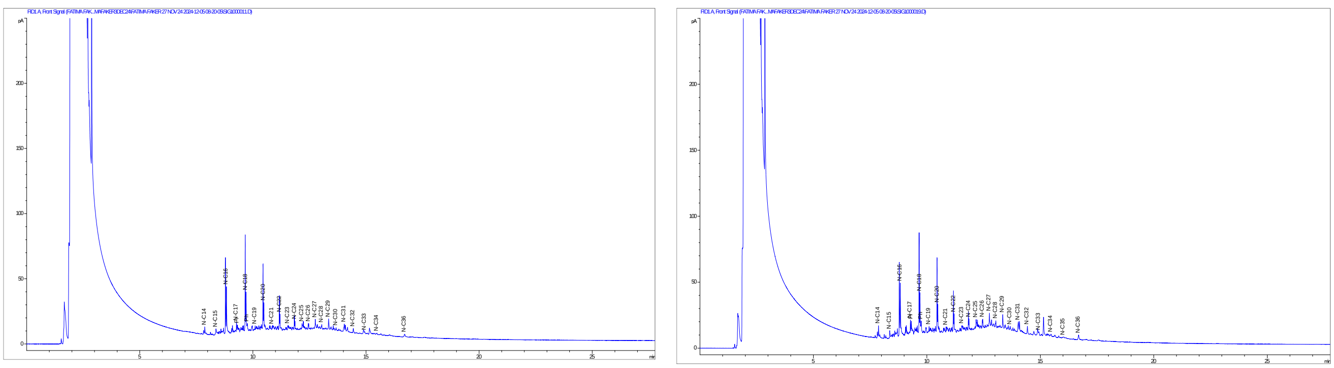
Table 6. Concentration of N-Alkane (µg/g dw) at station 5

N-alkane Component Name	Core 5									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
n-C8	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C9	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C10	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C11	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
n-C12	**0**	**0**	**0**	**0**	**0**	**0.01036**	**0**	**0.00421**	**0.00492**	**0.00435**
n-C13	**0.01693**	**0.00794**	**0**	**0.00397**	**0**	**0.03054**	**0.00612**	**0.0059**	**0.01192**	**0.03448**
n-C14	**0.23882**	**0.23657**	**0.1087**	**0.14372**	**0.18218**	**0.4503**	**0.20241**	**0.16542**	**0.2254**	**0.26657**
n-C15	**0.2196**	**0.20438**	**0.06058**	**0.07285**	**0.22395**	**0.45735**	**0.17211**	**0.09948**	**0.20806**	**0.2128**
n-C16	**0.51999**	**0.78938**	**0.3621**	**0.4267**	**0.73277**	**0.80725**	**0.64515**	**0.45234**	**0.49104**	**0.71131**
n-C17	**0.292**	**0.27973**	**0.1162**	**0.14336**	**0.40846**	**0.43035**	**0.22879**	**0.16021**	**0.28394**	**0.31126**

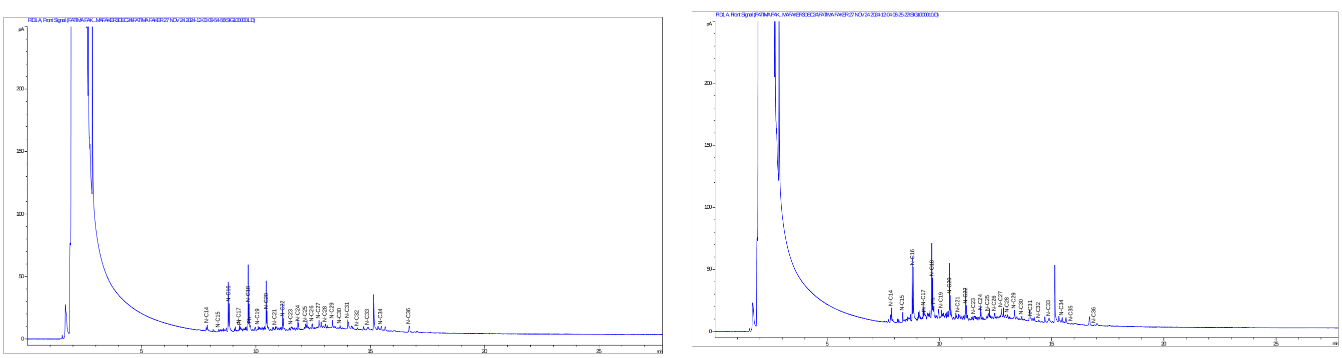
Pr	**0.19445**	**0.22599**	**0.07711**	**0.08596**	**0.21432**	**0.32107**	**0.16529**	**0.10482**	**0.20926**	**0.22738**
n-C18	**0.51942**	**0.54504**	**0.34419**	**0.37588**	**0.48766**	**0.68057**	**0.44006**	**0.36725**	**0.5265**	**0.6069**
Ph	**0.46669**	**0.55418**	**0.19632**	**0.21637**	**0.5005**	**0.75347**	**0.35108**	**0.26723**	**0.55683**	**0.26831**
n-C19	**0.25838**	**0.21897**	**0.10032**	**0.11064**	**0.23807**	**0.33701**	**0.17149**	**0.1435**	**0.2901**	**0.30462**
n-C20	**0.46577**	**0.42363**	**0.34743**	**0.32923**	**0.41037**	**0.64056**	**0.35963**	**0.34651**	**0.5394**	**0.68382**
n-C21	**0.21066**	**0.15009**	**0.08226**	**0.10755**	**0.20354**	**0.38594**	**0.14719**	**0.1492**	**0.30384**	**0.402**
n-C22	**0.363**	**0.30458**	**0.25175**	**0.28455**	**0.26028**	**0.53312**	**0.28318**	**0.24671**	**0.36824**	**0.47154**
n-C23	**0.29321**	**0.20368**	**0.15577**	**0.20668**	**0.29072**	**0.55251**	**0.22396**	**0.2607**	**0.50178**	**0.71179**
n-C24	**0.23358**	**0.15683**	**0.12456**	**0.17784**	**0.21205**	**0.40634**	**0.17653**	**0.20402**	**0.32578**	**0.39506**
n-C25	**0.58426**	**0.36539**	**0.29919**	**0.41611**	**0.47562**	**0.92179**	**0.30902**	**0.45059**	**0.75096**	**0.96139**
n-C26	**0.3606**	**0.21308**	**0.18094**	**0.28562**	**0.21152**	**0.4918**	**0.17997**	**0.18852**	**0.75905**	**0.99228**
n-C27	**0.70603**	**0.42078**	**0.36255**	**0.52466**	**0.57032**	**1.26836**	**0.55055**	**0.55034**	**0.95368**	**1.26544**
n-C28	**0.76402**	**0.255**	**0.21684**	**0.52169**	**0.6259**	**1.50011**	**0.62312**	**0.59451**	**1.07432**	**1.27086**
n-C29	**0.73947**	**0.42988**	**0.40139**	**0.57199**	**0.61992**	**1.32184**	**0.56409**	**0.56578**	**1.04691**	**1.34661**
n-C30	**0.52833**	**0.38423**	**0.25584**	**0.36318**	**0.43716**	**1.06352**	**0.42763**	**0.39499**	**0.77438**	**0.98139**
n-C31	**0.59083**	**0.35565**	**0.37625**	**0.46254**	**0.52785**	**0.43018**	**0.54856**	**0.18809**	**0.33749**	**0.50141**
n-C32	**0.45038**	**0.21432**	**0.18676**	**0.3041**	**0.36694**	**0.92482**	**0.39898**	**0.32606**	**0.75744**	**1.02377**
n-C33	**0.47394**	**0.24832**	**0.23478**	**0.31358**	**0.354**	**0.78432**	**0.25424**	**0.16224**	**0.73759**	**0.99247**
n-C34	**0.24619**	**0.13294**	**0.11668**	**0.04595**	**0.18298**	**0.10268**	**0.27939**	**0.16521**	**0.40914**	**0.19467**
n-C35	**0.33197**	**0.10992**	**0.06887**	**0.08111**	**0.04685**	**0.18164**	**0.15567**	**0.05744**	**0.12042**	**0.07343**
n-C36	**0.01281**	**0.0824**	**0.01472**	**0.01325**	**0.011**	**0.01901**	**0.0443**	**0.00937**	**0.12507**	**0.14221**
n-C37	**0.02832**	**0.02348**	**0.02429**	**0.02757**	**0.00627**	**0.00381**	**0.01983**	**0.02487**	**0.02617**	**0.0702**
n-C38	**0**	**0**	**0**	**0**	**0**	**0.01147**	**0**	**0**	**0.00692**	**0.01278**
n-C39	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.00757**	**0.03067**
n-C40	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.00449**



Core 1 GC Chromatograms

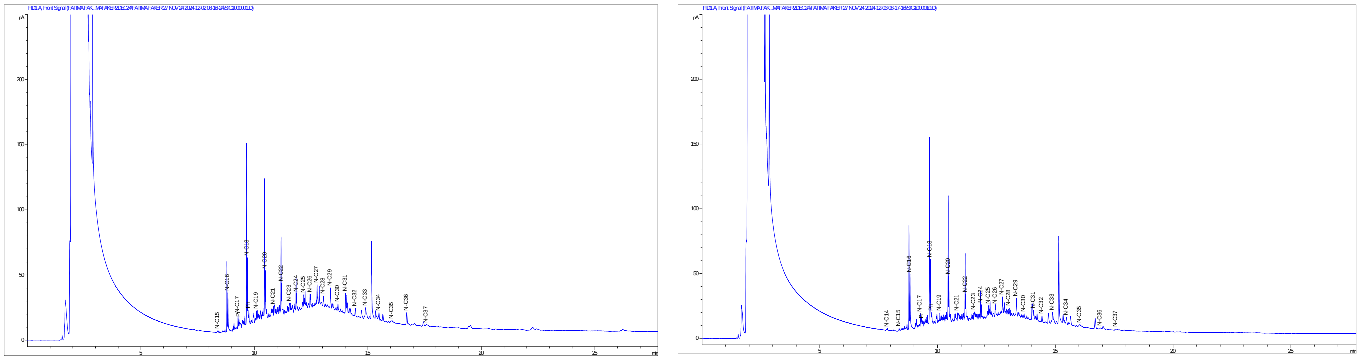


Core 2 GC Chromatograms

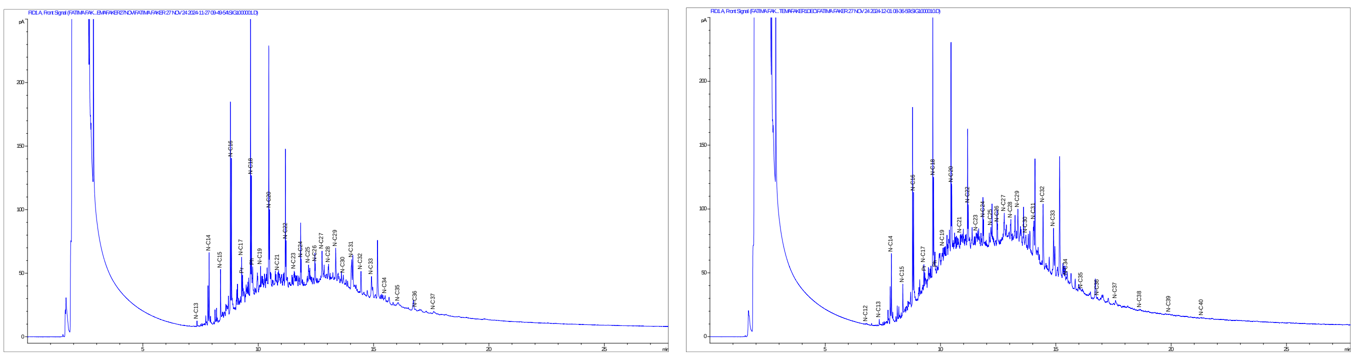


Core 3 GC Chromatograms

Fig. 2. GC chromatograms for the first, second and third stations



Core 4 GC Chromatograms



Core 5 GC Chromatograms

Fig. 3. GC chromatograms for fourth and fifth stations

Table 7. The total concentrations of N-alkane in the study cores (µg/g dw)

Stations	Total concentration of N-alkane									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Core 1	**2.2095**	**2.1715**	**5.1018**	**14.5073**	**6.33206**	**2.6426**	**1.5249**	**1.2786**	**0.54299**	**1.0379**
Core 2	**1.6581**	**1.27805**	**1.1302**	**1.3021**	**1.1665**	**1.6813**	**1.9118**	**1.9167**	**2.0264**	**ND**
Core 3	**0.9126**	**1.2315**	**1.4978**	**1.39503**	**1.86905**	**2.0888**	**1.9745**	**0.1836**	**0.1828**	**1.6222**
Core 4	**8.8012**	**2.2691**	**3.8236**	**2.5321**	**3.4964**	**2.2326**	**4.2919**	**2.4395**	**2.40808**	**2.7023**
Core 5	**10.1096**	**7.5363**	**5.0663**	**6.6166**	**8.8012**	**15.82209**	**7.9283**	**6.6555**	**12.7341**	**15.4762**

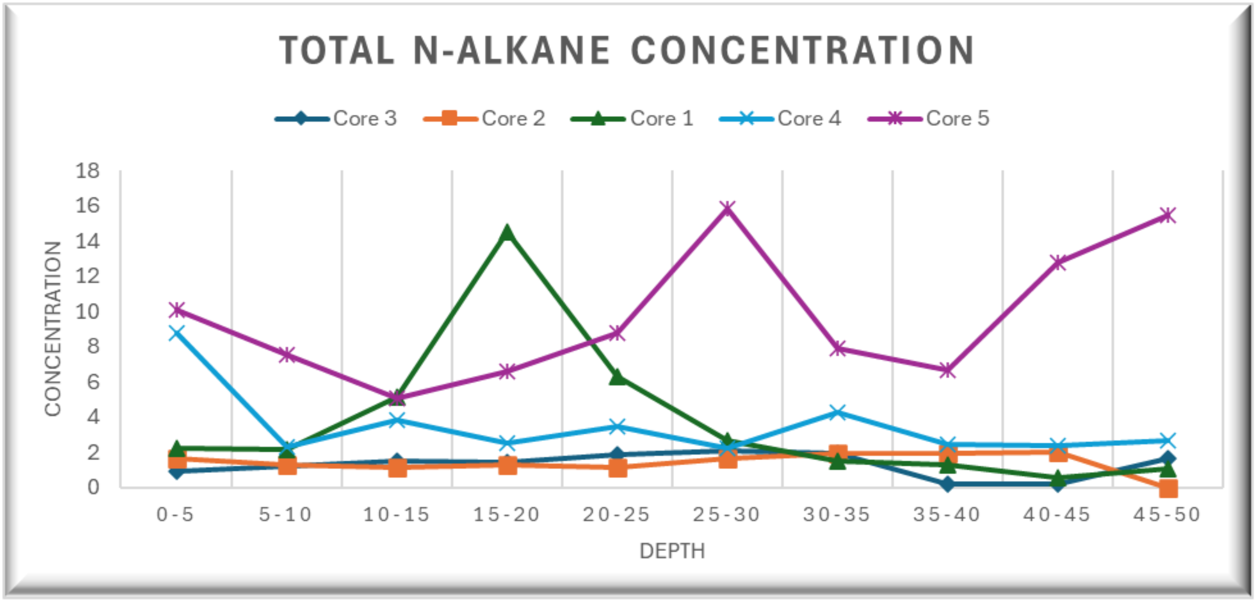


Fig. 4. The gradient of total concentration of N-alkane in five stations

Carbon preference index (CPI)

The CPI is used to differentiate between biogenic (typically >1) and petrogenic (typically ≈1) sources of alkanes. The highest CPI value was recorded at Station 2 (3.198), indicating a strong biogenic input. In contrast, the lowest CPI value was observed at Station 1 (0.494), suggesting a possible petroleum-related source.

Pristane/phytane ratio (Pri/Phy)

This ratio helps identify the redox conditions and potential origin of organic matter. The lowest Pri/Phy value was found at Station 2 (0.193), while the highest was recorded at Station 1 (1.155), indicating variability in the depositional environment and organic input.

C_{17}/pristane ratio (C17/Pri):

This ratio is commonly used to assess petroleum contamination. The lowest C17/Pri value occurred at Station 1 (0.506), while Station 2 had the highest value (2.668), suggesting stronger petroleum influence at Station 2.

C_{18}/phytane ratio (C18/Phy)

Similarly, this ratio provides insight into hydrocarbon sources. The highest C18/Phy was observed at Station 1 (3.484), while the lowest was at Station 5 (0.903), again indicating spatial differences in hydrocarbon origin.

Table 8. The N-Alkane indices for the first, second and third core

Station	Depth (cm)	CPI	Description	Pri/Phy	Description	C17/Pri	C18/Phy
Core 1	0-5	**0.7775**	**Anthropogenic**	**0.31654**	**Anthropogenic**	**1.0735**	**2.77004**
	5-10	**0.801**	**Anthropogenic**	**0.3858**	**Anthropogenic**	**0.6385**	**1.6563**
	10-15	**1.014**	**Biogenic**	**1.1553**	**Biogenic**	**0.72607**	**2.6872**
	15-20	**0.8181**	**Anthropogenic**	**0.5188**	**Anthropogenic**	**1.9137**	**1.7883**
	20-25	**1.079**	**Biogenic**	**0.4149**	**Anthropogenic**	**0.7027**	**1.1294**
	25-30	**0.9131**	**Anthropogenic**	**0.4574**	**Anthropogenic**	**0.7873**	**1.9031**
	30-35	**0.766**	**Anthropogenic**	**0.5507**	**Anthropogenic**	**0.7267**	**2.1242**
	35-40	**0.841**	**Anthropogenic**	**0.5801**	**Anthropogenic**	**0.5425**	**3.1157**
	40-45	**0.5259**	**Anthropogenic**	**0.6019**	**Anthropogenic**	**0.5088**	**2.5706**
	45-50	**0.4942**	**Anthropogenic**	**0.6507**	**Anthropogenic**	**0.50609**	**3.4841**
	0-5	**0.7906**	**Anthropogenic**	**0.7305**	**Anthropogenic**	**0.8211**	**1.7666**
	5-10	**0.8732**	**Anthropogenic**	**0.8622**	**Anthropogenic**	**0.7024**	**1.4254**

Core 2	10-15	**0.6967**	**Anthropogenic**	**0.6797**	**Anthropogenic**	**0.6656**	**1.2831**
	15-20	**0.7568**	**Anthropogenic**	**0.1928**	**Anthropogenic**	**2.05302**	**1.3033**
	20-25	**0.7405**	**Anthropogenic**	**0.2385**	**Anthropogenic**	**2.4595**	**1.2932**
	25-30	**0.7892**	**Anthropogenic**	**0.6742**	**Anthropogenic**	**0.7307**	**1.5045**
	30-35	**0.8188**	**Anthropogenic**	**0.78209**	**Anthropogenic**	**0.8423**	**1.6529**
	35-40	**0.8712**	**Anthropogenic**	**0.2283**	**Anthropogenic**	**2.6675**	**1.1936**
	40-45	**0.8877**	**Anthropogenic**	**0.7479**	**Anthropogenic**	**1.0103**	**1.46804**
Core 3	0-5	**0.7181**	**Anthropogenic**	**0.6863**	**Anthropogenic**	**0.7732**	**2.2972**
	5-10	**0.9671**	**Anthropogenic**	**0.6585**	**Anthropogenic**	**0.7188**	**2.4698**
	10-15	**0.8871**	**Anthropogenic**	**0.5381**	**Anthropogenic**	**0.7708**	**1.4953**
	15-20	**1.3979**	**Biogenic**	**0.5729**	**Anthropogenic**	**0.7519**	**1.8964**
	20-25	**0.8805**	**Anthropogenic**	**0.6777**	**Anthropogenic**	**0.8338**	**1.4088**
	25-30	**0.8878**	**Anthropogenic**	**0.6389**	**Anthropogenic**	**0.78315**	**1.3986**
	30-35	**0.8463**	**Anthropogenic**	**0.6823**	**Anthropogenic**	**0.7517**	**1.2391**
	35-40	**1.3576**	**Biogenic**	**0.6994**	**Anthropogenic**	**0.9246**	**3.0896**

	40-45	**0.6081**	**Anthropogenic**	**0.7901**	**Anthropogenic**	**0.9375**	**3.1527**
	45-50	**0.7627**	**Anthropogenic**	**0.2107**	**Anthropogenic**	**2.3222**	**1.1187**

Table 9. The N-Alkane indices for the fourth and fifth core

Station	Depth (cm)	CPI	Description	Pri/Phy	Description	C17/Pri	C18/Phy
Core 4	0-5	**1.0068**	**Biogenic**	**0.4282**	**Anthropogenic**	**1.9058**	**0.9743**
	5-10	**0.8346**	**Anthropogenic**	**0.3459**	**Anthropogenic**	**1.2296**	**1.84403**
	10-15	**1.3829**	**Biogenic**	**0.64809**	**Anthropogenic**	**1.0894**	**1.7778**
	15-20	**1.0045**	**Biogenic**	**0.3353**	**Anthropogenic**	**2.0894**	**2.1058**
	20-25	**0.9482**	**Anthropogenic**	**0.3365**	**Anthropogenic**	**1.7391**	**1.6346**
	25-30	**0.5005**	**Anthropogenic**	**0.3545**	**Anthropogenic**	**1.3812**	**1.7948**
	30-35	**0.8568**	**Anthropogenic**	**0.4055**	**Anthropogenic**	**1.2383**	**1.6358**
	35-40	**0.7181**	**Anthropogenic**	**0.4146**	**Anthropogenic**	**1.2008**	**1.8616**
	40-45	**0.9342**	**Anthropogenic**	**0.34403**	**Anthropogenic**	**1.2299**	**2.2121**
	45-50	**0.887**	**Anthropoge**	**0.2136**	**Anthropoge**	**2.0747**	**1.7090**

		5	**nic**		**nic**		**8**
Core 5	0-5	**1.0592**	**Biogenic**	**0.4166**	**Anthropogenic**	**1.5016**	**1.1129**
	5-10	**0.8597**	**Anthropogenic**	**0.4077**	**Anthropogenic**	**1.2377**	**0.9835**
	10-15	**0.9502**	**Anthropogenic**	**0.3927**	**Anthropogenic**	**1.5069**	**1.7532**
	15-20	**1.0289**	**Biogenic**	**0.3972**	**Anthropogenic**	**1.6677**	**1.7537**
	20-25	**1.0068**	**Biogenic**	**0.4282**	**Anthropogenic**	**1.9058**	**0.9743**
	25-30	**0.9852**	**Anthropogenic**	**0.9145**	**Anthropogenic**	**1.3403**	**0.9032**
	30-35	**0.8671**	**Anthropogenic**	**0.4708**	**Anthropogenic**	**1.3841**	**1.2534**
	35-40	**0.8534**	**Anthropogenic**	**0.3922**	**Anthropogenic**	**1.5284**	**1.3742**
	40-45	**0.9043**	**Anthropogenic**	**0.3758**	**Anthropogenic**	**1.3568**	**0.9455**
	45-50	**0.959**	**Anthropogenic**	**0.8474**	**Anthropogenic**	**1.3688**	**2.2619**

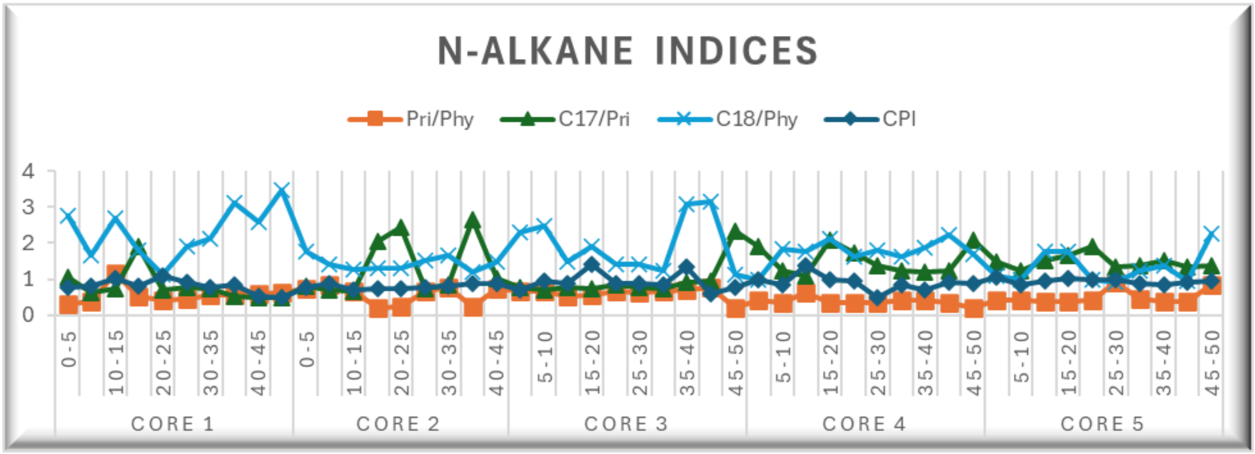


Fig. 5. The N-Alkane indices comparison

DISCUSSION

Ratio of pristane to phytane (Pri/Phy)

Pristane (2,6,10,14-tetramethylpentadecane) and phytane (2,6,10-tetramethylhexadecane) are useful indicators of petroleum hydrocarbon contamination **(NRC, 2003)**. A pristane-to-phytane ratio greater than 1 indicates biogenic sources, while a ratio of 1 or less suggests pollution from petroleum hydrocarbons or other anthropogenic sources **(Mzoughi & Chouba, 2011)**.

Carbon preference index (CPI)

The carbon preference index (CPI) is defined as the ratio of the total concentrations of odd-numbered carbon atoms to the total concentrations of even-numbered carbon atoms in *n*-alkanes. This index provides valuable information for determining and assessing anthropogenic contributions of *n*-alkanes to the environment **(Weifang *et al.*, 2010)**. For example, *n*-alkanes from anthropogenic sources typically have CPI values of about 1 or less, while *n*-alkanes from biogenic sources usually show CPI values greater than 1 **(Fagbote *et al.*, 2013)**.

Ratios of C17/pristane and C18/phytane

The ratios of C17 to pristane and C18 to phytane provide insight into the source of oil and the extent of hydrocarbon weathering. A ratio less than 1 indicates weathered oil, while a higher ratio suggests the presence of unweathered hydrocarbons **(Harji *et al.*, 2008)**.

n-Alkanes detected in this study ranged from C8 to C40, with homologs from C14 to C37 found in the greatest concentrations. In the C12–C24 even-numbered *n*-alkane range, inputs of microbial or petroleum-derived organic carbon are inferred. Conversely, the co-occurrence of even-numbered and predominantly odd-numbered *n*-alkanes (especially C15 through C33, including C23, C25, C27, C29, and C31) indicates a biogenic input primarily from higher terrestrial plants **(Farid, 2017)**.

The distinctive characteristics of straight-chain *n*-alkanes and their resistance to diagenetic alteration make them useful biomarkers in sediment studies of paleoenvironments and paleoecology. Short-chain odd-carbon *n*-alkanes (e.g., n-C15, n-C17, and n-C19) are abundant in phytoplankton, while mid-chain (n-C21, n-C23, n-C25) and long-chain (n-C29, n-C31, n-C33) *n*-alkanes typically originate from submerged or floating macrophytes and terrestrial plants **(Zhang *et al.*, 2020)**.

Additionally, guidelines from **Chen *et al.* (2021)** indicate that diatoms are common sources of even-carbon *n*-alkanes, while C22 and C24 are likely derived from bacteria **(Al-Bidhani *et al.*, 2020)**. Lower molecular weight *n*-alkanes (C9–C15) may evaporate or be metabolized by food web microorganisms, whereas higher molecular weight *n*-alkanes (C33–C36) are more resistant to biological degradation and may persist in sediments and the water column. This may explain the relatively low or nearly undetected concentrations of C10–C15 observed in this study.

Phytane is generally associated with oil, while pristane is more commonly derived from zooplankton **(Guerra-Garcia *et al.*, 2003)**.

The high levels of *n*-alkanes observed in this study could be linked to historic oil exploration and development in the region **(Li *et al.*, 2020)**. In aquatic systems, odd-carbon-numbered compounds (C15, C17, and C19) are often associated with phytoplankton or algal sources **(Thomas *et al.*, 2021)**, while compounds such as C25, C27, C29, and C31 are commonly used as biomarkers for terrestrial plant-derived organic matter **(Zhan *et al.*, 2022)**.

The presence of petroleum *n*-alkanes in sediments poses serious environmental concerns due to their persistence, which can compromise ecological stability and harm surrounding biota. *n*-Alkanes have been shown to bioaccumulate in marine environments, transferring hydrocarbons to higher trophic levels **(Jafarabadi *et al.*, 2018; Wang *et al.*, 2019)**. The bioaccumulation of *n*-alkanes in marine species, particularly fish, is well documented **(Valavanidis *et al.*, 2006; Al-Khion *et al.*, 2021)**.

The toxic effects of *n*-alkanes on marine organisms are also well established. These compounds can smother marine organisms, interfere with respiration, inhibit feeding, and disrupt biological membranes, leading to cellular damage. For instance, *n*-alkanes can induce oxidative stress in marine organisms, causing irreversible cellular damage and impairing physiological functions **(Sardi *et al.*, 2016)**. Chronic exposure to low concentrations has also been linked to liver damage—due to altered enzyme activity—and reproductive issues **(Rico-Martinez *et al.*, 2013)**.

Table (10) shows a comparison between findings from previous studies and the results of the current study.

Table 10. The comparison between the current study and some of previous studies

Researcher name	Study area	N-alkane Concentrations (µg/g DW	Chain length
Tolosa *et al.*, 2005	Eastern Gulf (UAE-Abu Dhabi)	0.02-2.5	C15-C40
De Mora *et al.*, 2010	Central Gulf (Qatar)	0.01-7.4	C12-C36
Al-Zaidan *et al.*, 2015	Northwest Arabian Gulf (Kuwait)	1.7-150	C10-C34
Farid, 2017	Shatt Al-arab River	0.08-42.58	C7-C31
Saleh *et al.*, 2020	Al-Hammar Marsh Southern Iraq	6.18-45.24	C7-C31
Aghadadashi *et al.*, 2021	Arabian Gulf	Not Specified	C16-C22
Current Study	Khor Al-Zubair (Northwest Arabian Gulf)	0.542-15.476	C8-C40

CONCLUSION

The study was conducted to determine the levels of naturally occurring alkanes at various stations in the Khor Al-Zubair area of southern Iraq. A total of approximately 36 compounds were identified. The highest concentrations were found at Station 5, most likely due to its proximity to nearby ports. In contrast, Station 3 recorded the lowest levels, likely influenced by its location near the mangrove forest project. The analysis also included calculated ratios to help identify the origins of the compounds, which were found to be of non-natural, anthropogenic origin. The study recommends continued monitoring of these compounds and efforts to limit their dispersion and environmental impact in the region.

REFERENCES

Al-Ali, B. S.; Alkhion, D. D.; Al-Saad, H. T. and Rushdi, A. I. (2022). Sources and apportionment of aliphatic hydrocarbons in freshwater fish species from Shatt Al-Arab River, Iraq. *Ecology, Environment and Conservation*, 28, S10-S22.

Al-Bidhani, M. F.; Saleh, S. M.; Khwedem, A. A. and Al-Saad, H. T. (2020). N-alkanes in the southern part of Al-Hammar marsh, Southern Iraq. *Ecology, Environment and Conservation*, 27(2), 716-721. https://www.envirobiotechjournals.com/EEC/v27i22021/EEC

Aghadadashi, V.; Mehdinia, A. and Molaei, S. (2021). Normal alkanes in sediments from the Persian Gulf: Spatial pattern and implications for autochthonous, allochthonous, and petroleum-originated contaminants. *Environmental Monitoring and Assessment*, 193(6), 364. https://doi.org/10.1007/s10661-021-09122-x

Al-Hejueje, M. M. (2014). *Application of water quality and pollution indices to evaluate the water and sediments status in the middle part of Shatt Al-Arab River*. Ph.D. Thesis, University of Basrah.

Al-Khion, D. D.; Al-Ali, B. S.; Al-Saad, H. T. and Rushdi, A. I. (2021). Levels and source of aliphatic hydrocarbons in marine fishes from coast of Iraq based on biomarkers and biogeochemical indices. *Indian Journal of Ecology*, 48(2), 536-544.

Al-Zaidan, A. S. Y.; Al-Kandari, M.; Al-Sarawi, H. A.; Obbard, J. P. and Al-Sarawi, M. A. (2015). Petroleum hydrocarbons and trace metals in nearshore gulf sediments of Kuwait. *Marine Pollution Bulletin*, 100(1), 539-546. https://doi.org/10.1016/j.marpolbul.2015.08.004

Chen, L.; Li, F.; Liu, J. and He, X. (2021). Multiple lipid biomarkers record organic matter sources and paleo-environmental changes in the East China Sea coast over the past 160 years. *The Holocene*, 31(1), 16-27. https://doi.org/10.1177/0959683620961500

De Mora, S.; Tolosa, I.; Fowler, S. W.; Villeneuve, J. P.; Cassi, R. and Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME Sea Area during 2005. *Marine Pollution Bulletin*, 60(12), 2323-2349. https://doi.org/10.1016/j.marpolbul.2010.09.021

Fagbote, O. E. and Olanipekun, E. O. (2013). Characterization and sources of aliphatic hydrocarbons of the sediments of River Oluwa at Agbabu Bitumen Deposit Area, Western Nigeria. *Journal of Science Research and Report*, 2(1), 228-248. https://doi.org/10.9734/JSRR/2013/3063

Farid, W. A. (2017). Assessment of aliphatic hydrocarbons in sediments of Shatt Al-Arab River, Southern Iraq, North East Arabian Gulf. *American Journal of Environmental Sciences*, 13(6), 398-411. https://doi.org/10.3844/ajessp.2017.398.411

Goutx, M. and Saliot, A. (1980). Relationship between dissolved and particulate fatty acid and hydrocarbons, chlorophyll (a) and zooplankton biomass in Ville Franche Bay, Mediterranean Sea. *Marine Chemistry*, 8(4), 299-318.

Grmashaet, R. A.; Al-Sareji, O. J.; Salman, J. M. and Hashim, K. S. (2020). Polycyclic aromatic hydrocarbons (PAHs) in urban street dust within three land-uses of Babylon governorate, Iraq: Distribution, sources, and health risk assessment. *Journal of King Saud University - Engineering Sciences*. https://doi.org/10.1016/j.jksues.2020.11.002

Guerra-García, J. M.; González-Vila, F. J. and García-Gómez, J. C. (2003). Aliphatic hydrocarbon pollution and microbenthic assemblages in Ceuta harbor: A multivariate approach. *Marine Ecology Progress Series*, 263, 127-138. https://doi.org/10.3354/meps263127

Harji, R. R.; Yvenat, A. and Bhosle, N. B. (2008). Sources of hydrocarbons in sediments of the Mandovi estuary and the Marmugoa harbour, west coast of India. *Environment International*, 34(7), 959-965. https://doi.org/10.1016/j.envint.2008.02.006

Harrison, R. M. (Ed.). (1996). *Pollution: Causes, effects and control* (3rd ed.). Royal Society of Chemistry.

Hazza, M. A. and Jassim, A. K. (2024). The effect of temperature on primary productivity of phytoplankton in Khor Al-Zubair Lagoon in Basra City, Iraq. *Egyptian Journal of Aquatic Biology & Fisheries*, 28(5), 1059-1070. https://doi.org/10.21608/ejabf.2024.382121

Jafarabadi, A. R.; Bakhtiari, A. R.; Laetitia, H.; Toosi, A. S. and Yap, C. K. (2018). First report of bioaccumulation and bioconcentration of aliphatic hydrocarbons (AHs) and persistent organic pollutants (PAHs, PCBs and PCNs) and their effects on alcyonacea and scleractinian corals and their endosymbiotic algae from the Persian Gulf, Iran: Inter- and intra-species differences. *Science of the Total Environment*, 627, 141-157.

Lafta, A. A.; Altaei, S. A. and Al-Hashimi, N. H. (2019). Characteristics of the tidal wave in Khor Abdullah and Khor Al-Zubair Channels, Northwest of the Arabian Gulf. *Mesopotamian Journal of Marine Sciences*, 34(2), 112-125. https://doi.org/10.58629/mjms.v34i2.32

Li, J.; Xu, Y.; Song, Q.; Yang, J.; Xie, L.; Yu, S. and Zheng, L. (2020). Polycyclic aromatic hydrocarbon and n-alkane pollution characteristics and structural and functional perturbations to the microbial community: A case-study of historically petroleum-contaminated soil. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-020-11301-1

Mzoughi, N. and Chouba, L. (2011). Distribution and partitioning of aliphatic hydrocarbons and polycyclic aromatic hydrocarbons between water, suspended particulate matter, and sediment in harbours of the west coastal of the Gulf of Tunis (Tunisia). *Journal of Environmental Monitoring*, 13, 689-698. https://doi.org/10.1039/c0em00616e

National Research Council (NRC). (2003). *Oil in the sea III: Inputs, fates, and effects*. National Academies Press.

Rico-Martínez, R.; Snell, T. W. and Shearer, T. L. (2013). Synergistic toxicity of Macondo crude oil and dispersant Corexit 9500A® to the Brachionus plicatilis species complex (Rotifera). *Environmental Pollution*, 173, 5-10.

Saleh, S. M.; Farhan, F. J.; Karem, D. S.; Al-Saad, H. T. and Al-Anbe, L. M. J. (2020). N-alkanes in sediment of Al-Hammar marsh, Southern Iraq. *Marsh Bulletin*, 15(1), 12-18.

Sardi, A. E.; Sandrini-Neto, L.; da Pereira, S. L.; Silva de Assis, H.; Martins, C. C.; Lana, P. D. C. and Camus, L. (2016). Oxidative stress in two tropical species after exposure to diesel oil. *Environmental Science and Pollution Research*, 23, 20952-20962.

Thomas, C. L.; Jansen, B.; van Loon, E. E. and Wiesenberg, G. L. B. (2021). Transformation of n-alkanes from plant to soil: A review. *Soil*, 7, 785-809. https://doi.org/10.5194/soil-7-785-2021

Tolosa, I.; de Mora, S.; Sheikholeslami, M. R.; Villeneuve, J. P.; Bartocci, J. and Cattini, C. (2005). Aliphatic and aromatic hydrocarbons in coastal Caspian Sea sediments. *Marine Pollution Bulletin*, 50(7), 783-790. https://doi.org/10.1016/j.marpolbul.2005.02.008

Valavanidis, A.; Vlahogianni, T.; Dassenakis, M. and Scoullos, M. (2006). Molecular biomarkers of oxidative stress in aquatic organisms in relation to toxic environmental pollutants. *Ecotoxicology and Environmental Safety*, 64(2), 178-189.

Wang, S.; Liu, G.; Yuan, Z. and Da, C. (2018). N-alkanes in sediments from the Yellow River Estuary, China: Occurrence, sources and historical sedimentary record. *Ecotoxicology and Environmental Safety*, 150, 199-206. https://doi.org/10.1016/j.ecoenv.2017.12.016

Wang, S.; Liu, G.; Yuan, Z. and Lam, P. K. (2019). Occurrence and trophic transfer of aliphatic hydrocarbons in fish species from Yellow River Estuary and Laizhou Bay, China. *Science of the Total Environment*, 696, 134037.

Weifang, L.; Yue, P. and Zhipeng, B. (2010). Distribution and sources of n-alkanes in PM2.5 at urban industrial and coastal sites in Tianjin, China. *Journal of Environmental Sciences*, 22(10), 1551-1557.

Wu, Y.; Zhang, J.; Mi, T. and Li, B. (2001). Occurrence of n-alkanes and polycyclic aromatic hydrocarbons in the core sediments of the Yellow Sea. *Marine Chemistry*, 76(1-2), 1-15. https://doi.org/10.1016/S0304-4203(01)00040-8

Zhang, Y.; Yu, J.; Su, Y.; Du, Y. and Liu, Z. (2020). A comparison of n-alkane contents in sediments of five lakes from contrasting environments. *Organic Geochemistry*, 139, 103943. https://doi.org/10.1016/j.orggeochem.2019.103943

Zhao, M.; Sun, H.; Liu, Z.; Bao, Q.; Chen, B.; Yang, M.; Yan, H.; Li, D.; He, H.; Wei, Y. and Cai, G. (2022). Organic carbon source tracing and the BCP effect in the Yangtze River and the Yellow River: Insights from hydrochemistry, carbon isotope, and lipid biomarker analyses. *Science of the Total Environment*, 812, 152429. https://doi.org/10.1016/j.scitotenv.2021.152429

Zhan, S.; Wu, J.; Zhang, H. and Jin, M. (2022). Occurrence, sources and spatial distribution of n-alkanes in surface soils from the Amu Darya Delta, Uzbekistan, arid Central Asia. *Environmental Research*, 214(3), 114063. https://doi.org/10.1016/j.envres.2022.114063