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Environmental Pollution Assessment of Inorganic Alkanes on Wheat (*Triticum aestivum*) and Barley (*Hordeum vulgare*) Crops in Northern Basrah, Southern Iraq

Fatimah I. AL-Zubaidi[1], Frias M.H. Al-Khatib[2] and Widad M.T. Al-Asadi[3]

[1-3]Department of Ecology, College of Science, University of Basrah, Basrah, Iraq.

[3]E-mail: widad.taher@uobasrah.edu.iq

Abstract. This study investigates the distribution and potential sources of n-alkanes in wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) samples collected from three stations (Nahr Al-Aiz, Al-Tiraba, and Um Al-Shewage) in Qurna, Basrah City. Total n-alkanes ranged from 684.8476 - 1711.891 ng/g in wheat and 1700.283 - 1848.977 ng/g in barley, with odd-carbon homologs (C27, C29 and C31). The concentrations of n-alkanes (C8–C40) were quantified, and diagnostic ratios, such as the carbon Preference Index (CPI), Pr/Ph, C17/Pr, and C18/Ph were calculated to identify biogenic and anthropogenic sources. The Carbon Preference Index (CPI) values (wheat:7.324-16.882; barley:3.988-5.812) indicate predominant biogenic origins (plant waxes). The results revealed distinct patterns in n-alkane distributions, with odd-numbered alkanes (C29, C31 and C33) dominating in barley, suggesting higher plant wax contributions, while wheat exhibited mixed sources. Comparisons with global studies confirm that Basrah grains have lower n-alkane pollution than industrial regions, but higher pollution than rural areas.

Keywords. n-Alkanes, Wheat, Barley, Basrah, GC–MS, Hydrocarbon sources.

1. Introduction

n-Alkanes are ubiquitous in terrestrial and aquatic environments, originating from natural (e.g., plant waxes, microbial activity) and anthropogenic sources (e.g., petroleum and industrial emissions) [1]. Their distribution patterns and diagnostic ratios serve as biomarkers for tracing sources of organic matter. In agricultural regions such as Qurna, understanding n-alkane profiles in crops such as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) is critical for assessing soil health and contamination risks [2].

Environmental pollution by hydrocarbons, particularly n-alkanes, is a growing concern in the agricultural ecosystems near industrial zones. Basrah, which is located in southern Iraq, is heavily influenced by oil extraction and refinery operations. These activities contribute to air, water, and soil contamination, thereby posing significant risks to crop safety and public health. Cereal crops such as wheat and barley are staples in the Iraqi diet. These crops can absorb pollutants from contaminated soil and from atmospheric deposition. n-Alkanes can serve as biomarkers for hydrocarbon pollution. This study aimed to quantify the levels of n-alkanes in wheat and barley crops from Basrah agricultural zones and assess their potential health and ecological risks [3].

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n-Alkanes are long-chain saturated hydrocarbons widely distributed in plants, soils, and sediments. They are important biomarkers for understanding plant physiology, environmental conditions, and agricultural practices. In wheat (Triticum aestivum) and barley (Hordeum vulgare), n-alkanes are primarily derived from the epicuticular waxes of leaves and stems and play a crucial role in reducing water loss and protecting against pathogens [1].
The distribution of n-alkanes in crops is influenced by genetic factors, environmental cnditions, and agricultural management practices. Typically, these compounds exhibit a strong odd-over-even carbon number predominance, with C27, C29, and C31 being the most abundant in cereals [4]. Studying their composition in wheat and barley grown in Basrah City can provide insights into local agricultural practices, climatic effects, and potential contamination sources (e.g., petroleum hydrocarbons or industrial pollutants).
Basrah City, which is located in a region with specific climatic and soil conditions, may exhibit unique n-alkane signatures in cereal crops. Possible sources include biological syntheses plant-derived n-alkanes from epicuticular waxes [5] and Anthropogenic Contamination, Fossil fuel residues from vehicular emissions, and industrial activities [6]. Soil organic matter, which decomposes plant material contributes to long-chain alkanes in crops [7]. Research is needed to characterize the specific n-alkane profiles in wheat and barley in Basrah City's and to distinguish between natural and anthropogenic sources.
n-Alkanes are saturated hydrocarbons prevalent in plant epicuticular waxes and serve as protective barriers against abiotic stressors (e.g., UV radiation and drought). Their distribution chain lengths, C19-C34, and odd-over-even predominance (OEP) are species-specific, making them valuable biomarkers for plant physiology and environmental monitoring [8]. In arid regions such as Basrah (Iraq), where soil salinity and pollution threaten cereal production, understanding n-alkane profiles in staple crops (wheat and barley) is critical for assessing plant adaptation and contamination risks. This study aimed to compare n-alkane concentrations in wheat and barley across three stations. Identification of potential sources using molecular indices. Evaluation of the environmental implications for Basrah’s agroecosystem

2. Materials and Methods

2.1. Study Area
Three stations were selected in the Al-Qurna District, north of Basra, Iraq, which are famous for growing wheat (*Triticum aestivum*) and Barley *(Hordeum vulgare*) (the study plants): Nahr Al-Ezz, Al-Taraba, and Umm Al-Shuwaij (Figure 1). These areas have agricultural characteristics and are located near oil-polluted areas (the West Qurna oil fields), surrounded by several oil refineries, pipelines, and refineries.

2.2. Sample Collection
Samples of vegetative growth of wheat and barley were collected from the selected stations during their growing season, from February, when growth begins, to June, when ear formation occurs.
The samples were brought to the laboratory and, after being cleaned of dead parts and soil, air-dried in the laboratory (Pollution Laboratory, Department of Ecology, College of Science, University of Basrah). After drying, the samples were ground using a ceramic mortar and sieved through a 63µm sieve. They were stored until extraction to determine petroleum hydrocarbons (n-alkanes).

2.3. Extraction Method
Five grams of sieved Wheat and Barley were placed in cellulose thimble and soxhlet extracted using soxhlet intermittent extraction according to the method of with mixed solvents (120 ml) methanol: benzene (1:1 v/v) for 48 hrs. at temperature doesn’t exceed 40°C. The combined extracts were saponified for 2h. by adding (15ml) 4M MeOH (KOH) at the same temperature and cooling to room temperature. The unsaponified matter was extracted with (50 ml) n-hexane using a separator funnel. a 20 cm glass column packed with glass wool, 8g silica gel (100-200 mesh), 4 g aluminum oxide (Al_2O_3,

100-200 mesh), and 4 g anhydrous sodium sulfate (Na_2SO3) at the top. The aliphatic component of n-alkanes was eluted using a hexane separation column [9].

GC-MS analysis of n-Alkanes (C8-C40) was performed using an Agilent 7890B gas chromatograph interfaced with an Agilent 5977A mass spectrometer. The temperature schedule of the GC oven was: starting temperature, 40°C ramped at a rate of 10°C/min to a final temperature of 310°C. The injector temperature was set to 260°C by employing split mode (ratio 75:1). The flow control was set to a constant flow of 7.0699 psi, total flow of 79 mL/min, column flow of 1 mL/min, and purge flow of 3 mL/min. mass spectrometer conditions: ion source temperature, 250°C quadrupole temperature 150°C interface temperature 280°C. the solvent cut time was constant at 4.00 minutes, with a start time of 4.00 minutes and end time 35.00-40.00 minutes. Individual n-alkanes were identified by comparing retention times and mass spectra with those of authentic standards and the NIST mass spectral library. Quantification was performed by external standard calibration using C8 - C40 n-alkane standards.

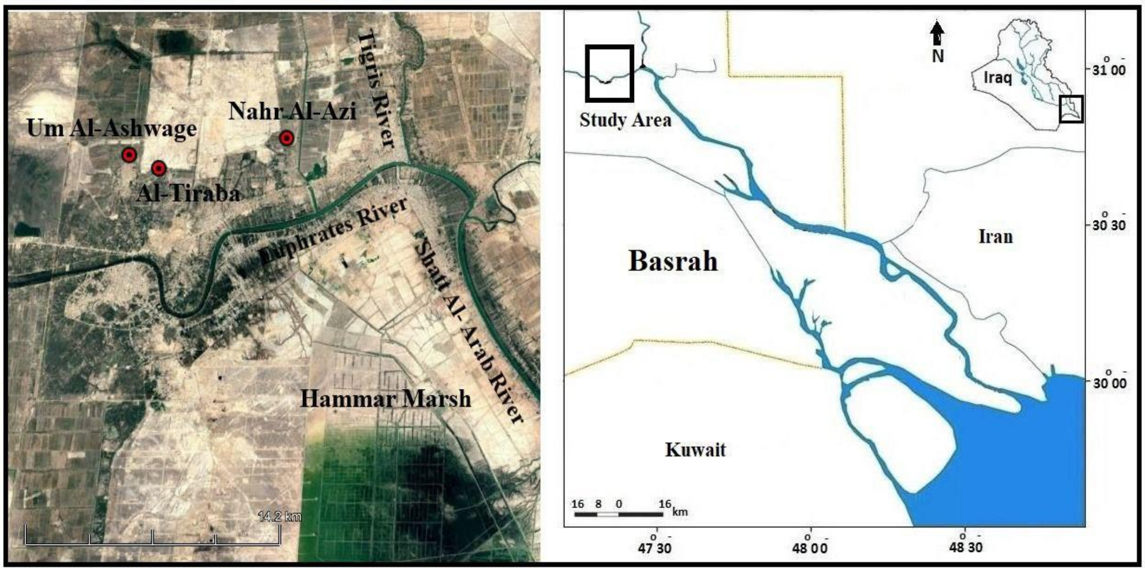

Figure 1. Samples location.

3. Results and Discussion

Total n-alkanes were higher in wheat in (St2: Al-Tiraba) mean:1711.891 ng/g, while lower weight in (St3: Um AlSewage) mean: 684.8476 ng/g, as shown in Table (1) and Fig(2). Total n-alkanes were higher in Barely (St2: Al-Tiraba) mean1848.977ng/g, while lower weight in (St1: Nahr AlAiz) mean: 1700.283 ng/g (Table 2 and Fig 3).

The Carbon Performance Index (CPI)Values in Wheat samples (2.732-16.88) as shown in Table (2) sites near oil fields (Qurna 1and2), While Barley (3.988-5.812). as shown in Table (4), indicate petrogenic input. [10,11].

The distribution of n-alkane chain lengths was consistent, displaying two unimodal distributions, with peaks at n-C27 and a ratio of (n-C26+C28 = 0.85–2.55), indicating a biogenic (terrestrial) source in wheat plants. The presence of n-alkanes with an even number of carbon atoms across all sites suggests the significance of terrestrial input. Long-chain alkanes (n-C25 – n-C35) are likely derived from plant cuticular waxes, epicuticular waxes, or other plastic substances. Analysis of leaf and peduncle samples from bierly plants showed n-alkane levels ranging from 20 to 250 ppm, characterized by a predominance of n-alkanes (n-C23 – n-C33) with odd-numbered predominance (n-C25/C29 = 0.89-27.5), reflecting predominant marine sources. The leaf and peduncle samples obtained from an oil-polluted area contained substantial amounts of long-chain n-alkanes (n-C27 – n-C31), likely originating from artificial aliphatic oils or detergents, indicating anthropogenic pollution in the study area [12,13].

The chromatograms of n-alkane hydrocarbons for both plants (wheat and barley) as illusulitrated in (Fig4and 5)respectively indicated that n-alkanes ranged from n-C18 to n-C36, with n-C29 and n-C31 being the most prevalent,. The concentration of n-alkanes in barley plants (based on dry weight) varied from (0.113 to 826.166 ng/g) with n-C29 exhibiting the highest concentration. Conversely, wheat plants showed concentrations ranging from (0.163 to 589.827 ng/g), with n-C29 as the dominant alkane. In summary, n-alkanes were identified in both wheat and other plants from particulate matter in Southern Iraq. The organic nature of these hydrocarbons, characterized by their high stability, non-polarity, and significance as anthropogenic sources, was noted, particularly for odd-numbered linear chain-length n-alkanes, which consist of a straight-chain saturated hydrocarbon group with the formula CnH2n+2. n-Alkanes were determined to originate from plant wax and/or animal sources in the study area. The maturity indices intedicte sediment deposition in a continental environment. The average maximum concentrations of n-alkanes from wheat and beerly agricultural composts were 116.79 and 725.66 μg/g OC, respectively. The organic geochemical source analysis indicated that the ratios of n-C17 and n-C15 were above 1, suggesting that the crops were primarily derived from terrestrial higher plant wax inputs, whereas a higher Cmax indicated the presence of fresh water algal material [11, 14]. The dominance of n-C29 and n-C31 in n-alkanes from wheat and agricultural soils, respectively. emphasized the influence of higher plant wax input in the study area [13].

The most important data regarding abnormal n-alkane concentrations in wheat and bierly grwon plants are illustrated in the figures. This demonstrates that n-alkanes in wheat plants had significant differences between the southern area and the other two monitored regions, while there was high similarity in n-alkane distributions and sources in mixed plants of the three regions regardless of inland and coastal conditions. A possible explanation for this difference is as follows: Wheat is one of the main crops in Iraq, and is planted in an area exceeding 60% of the country's total cropland. Because of its importance to food security, wheat cultivation may be greatly intensified with irrigation in the southern area, resulting in an irrigation influence signal on wheat plant n-alkanes.

For Globul comparison Basrah's grains had lower n-alkanes than industrially exposed regions (e.g., China's Yangtze Delta) but higher n-alkanes than agricultural zones (e.g., Turkey) (Table 5). Petrogenic contributions in Basrah were lower than those in oil-refining zones (e.g., India) but significant compared to uncontaminated regions.

Table 1. Concentration of n-Alkanes compound (ng/g) in Wheat (*Triticum aestivum*).

Compounds	St1	St2	St3	Compounds	St1	St2	St3
n-C8	0	0	0	n-C24	5.7598	6.9023	0.7617
n-C9	0	0	0	n-C25	44.3706	30.4575	9.2243
n-C10	0	0	0	n-C26	10.8181	12.4464	2.8258
n-C11	0	0	0	n-C27	69.3755	78.4553	24.4169
n-C12	0	0.3676	0	n-C28	28.4987	25.6078	4.9762
n-C13	0	0.4309	0	n-C29	151.7055	219.4875	12.7694
n-C14	0.4715	8.3142	1.8810	n-C30	27.9646	38.3134	15.1270
n-C15	2.1390	6.2413	1.4205	n-C31	348.8066	589.8278	316.3170
n-C16	14.5089	22.0711	3.4843	n-C32	18.1732	13.9388	0
n-C17	6.0390	8.9242	0.9849	n-C33	126.6313	114.8085	43.3181
Pr	2.1076	2.6242	0	n-C34	19.7124	14.0680	4.0884
n-C18	13.0862	19.2234	1.6648	n-C35	10.9663	9.2274	3.3338
ph	2.4186	3.7049	0.3015	n-C36	0.1477	0.1670	0
n-C19	4.6116	8.7287	1.0975	n-C37	0.3965	0.1636	0
n-C20	8.7103	10.5458	1.6212	n-C38	0	0	0
n-C21	351.6838	443.7330	230.4240	n-C39	0	0	0
n-C22	6.5872	10.3413	1.8494	n-C40	0	0	0
n-C23	14.4074	12.7688	2.9598	Total	1290.098	1711.891	684.8476

Table 2. Indices of n-Alkanes compound (ng/g) in Wheat (*Triticum aestivum*).

Odd	1131.133	1523.254	646.266
even	154.438	182.307	38.279
CPI	7.324	8.355	16.882
Pri/Phy	0.871	0.708	0

c17/Pri	2.865	3.400	0.984
c18/Phy	5.410	5.188	5.521

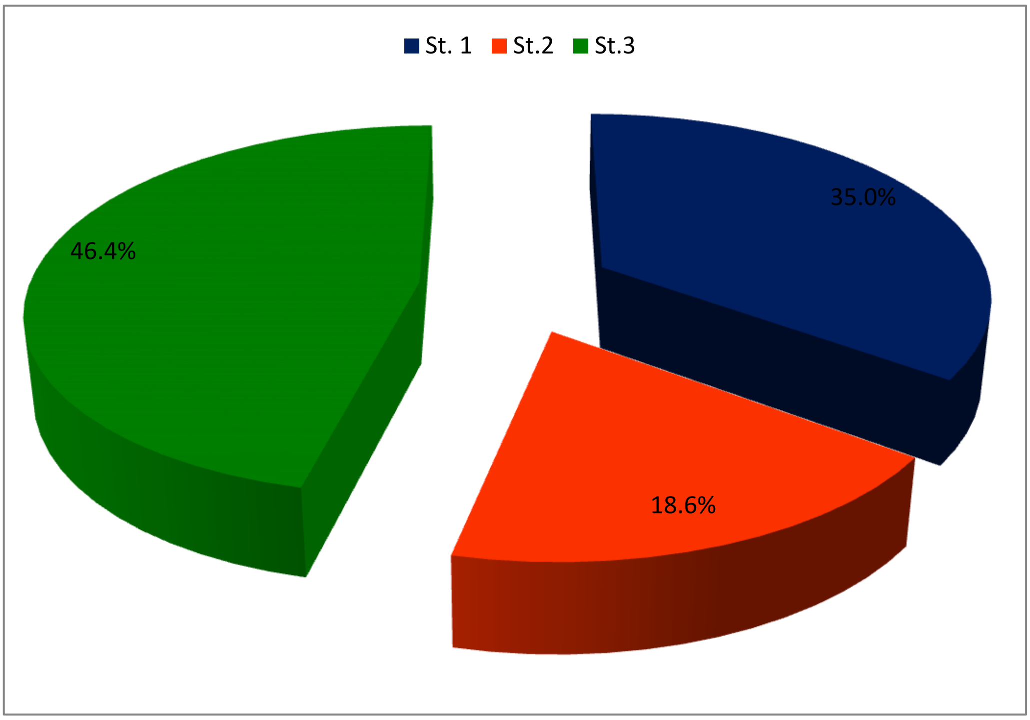

Figure 2. Total Concentration of n-Alkanes compound (ng/g) in Wheat (*Triticum aestivum*).

Table 3. Concentration of n-Alkanes compound (ng/g) in barley (*Hordeum vulgare*).

Compounds	St1	St2	St3	Compounds	St1	St2	St3
n-C8	0	0	0	n-C24	11.01414	15.44304	9.0146885
n-C9	0	0	0	n-C25	62.77451	76.79341	55.077031
n-C10	0	0	0	n-C26	18.82653	27.12743	18.617061
n-C11	0	0	0	n-C27	34.89067	66.52243	59.56303
n-C12	0.123615	0	0.1477736	n-C28	39.53607	41.99668	30.718257
n-C13	0.120016	0.113092	0.4100691	n-C29	862.1664	466.4265	745.3755
n-C14	11.51989	8.001127	4.5577276	n-C30	34.85889	37.1075	29.615627
n-C15	5.486873	5.27567	3.9550369	n-C31	72.45616	136.0971	47.756432
n-C16	21.5932	24.90979	16.674077	n-C32	16.98245	28.4635	28.908968
n-C17	5.91394	35.08182	7.5255955	n-C33	145.4792	72.56396	138.96125
Pr	4.257743	8.873193	4.3777067	n-C34	18.08367	28.79029	28.418003
n-C18	13.40171	16.77639	12.184535	n-C35	19.34135	20.53395	31.16634
Ph	5.771707	8.887207	5.3960067	n-C36	1.079967	0	2.232
n-C19	8.482923	12.81329	21.04296	n-C37	0.706233	0.4335	1.5199333
n-C20	10.2677	33.14611	8.7484464	n-C38	0	0	0
n-C21	212.3533	555.1559	388.76668	n-C39	0	0	0
n-C22	9.843413	28.81821	22.344349	n-C40	31.26796	49.21705	40.579145
n-C23	21.68238	43.60943	15.870269	Total	1700.283	1848.977	1779.5245

Table 4. Indices of n-Alkanes compound (ng/g) in barley (*Hordeum vulgare*).

Odd	1379.398	1355.323	1469.2337
even	238.3992	339.7971	252.76066
CPI	5.786083	3.988624	5.8127467
Pri/Phy	0.737692	0.998423	0.8112864
c17/Pri	1.388985	3.953686	1.7190726
c18/Phy	2.321967	1.887702	2.2580653

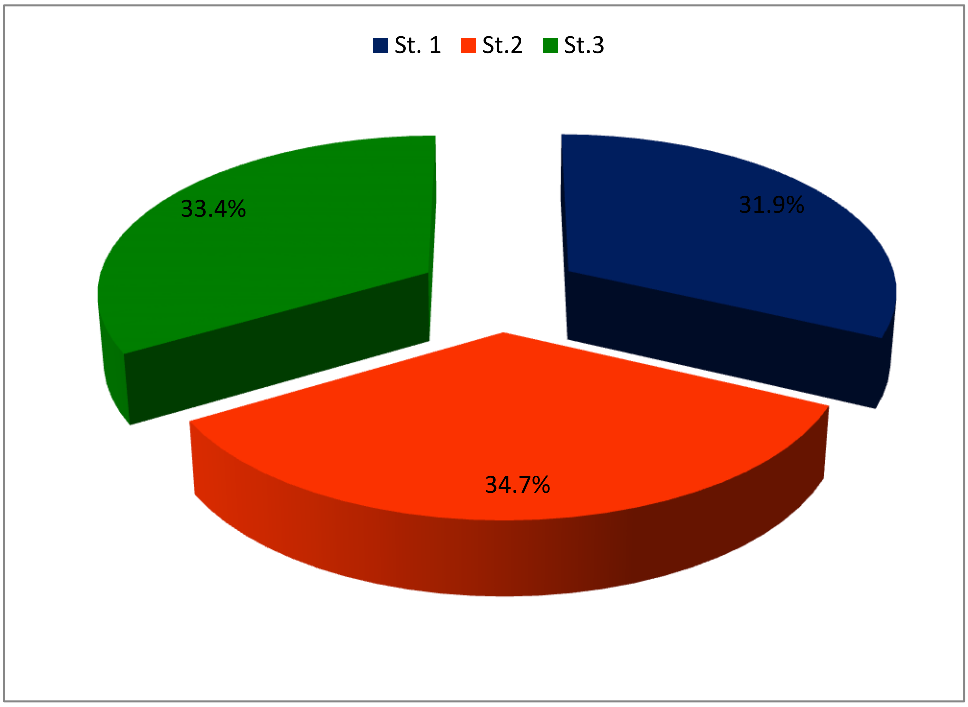

Figure 3. Total Concentration of n-Alkanes compound (ng/g) in barley (*Hordeum vulgare*).

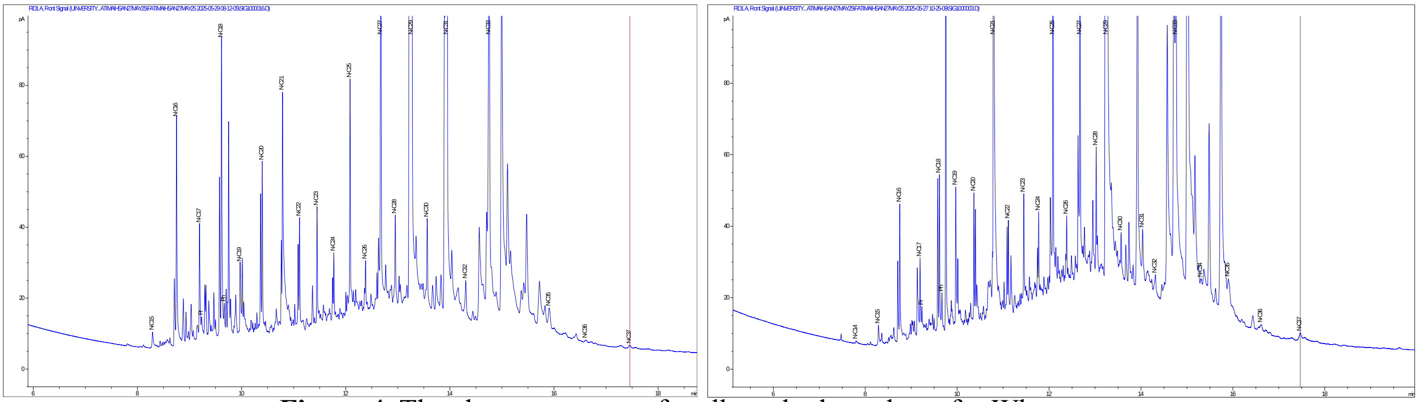

Figure 4. The chromatograms of n-alkane hydrocarbons for Wheat.

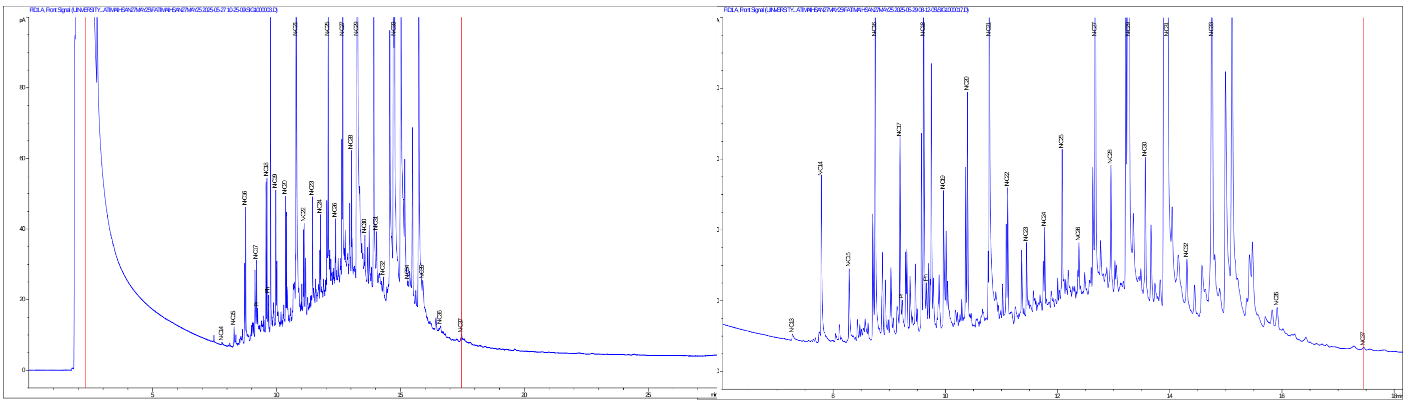

Figure 5. The chromatograms of n-alkane hydrocarbons for barley.

Table 5. Comparison of n-Alkanes Concentrations in Wheat and Barley from Different Regions of the World.

Country / Region	Plant Type	Aliphatic Concentration (µg/kg dry weight)	Number of PAHs Measured	Reference
China (Hebei)	Wheat	32.4	n-Alkanes C10–C35	[15]
India (Bihar)	Wheat	27.9	C12-C34	[16]
Iraq (Basra)	Barley	0.11	C12-C37	Current Study
Iraq (Basra)	Wheat	0.16	C12-C37	Current Study
Iran (Persia)	Barley	25.1	C13-C33	[17]
Egypt (Minya)	Wheat	18.7	C10-C30	[18]

Conclusion

n-alkanes in Basrah's wheat and barley are primarily derived from plant waxes, but petrogenic sources contribute to nearby industrial zones. The total concentrations are moderate globally, yet CPI values reveal localized petroleum contamination. Mitigation strategies (e.g., soil remediation and barrier crops) should target high-risk sites. Future studies should analyze the co-pollutants (PAHs and metals).

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