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Methane and Hydrocarbon Emission Rates from Oil and Gas Production in the Province of Basra, South of Iraq

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Abstract. Petroleum deposits typically contain a gaseous component known as "associated gas". If associated gas is not collected or used on-site, it may be flared or vented as a byproduct of oil production. Flaring is preferential to venting in terms of global warming. Flaring oxidizes carbon and produces CO_2, but by destroying methane and other hydrocarbons, it decreases the overall risk of global warming emissions. On a 100-year time scale, fossil methane is 36 times more potent than CO_2. The measurements were taken at six oil fields (AlTuba, Allhais, Artawi, North Rumaila, Nahran Omar, and Majnoon) and two power plants (Alnajebia power plant and Shatt Al-Basra). To measure the concentrations of hydrocarbons, a direct measurement was taken for six months. ANOVA test was used to analyze the results at $p \leq 0.05$ and a correlation between hydrocarbon concentrations, wind speed, and temperature was done. The result showed that the hydrocarbons were found in all stations, in all measurements with different concentrations except in Alnajebia and Shatt Al -Basra power plant at first measurements, the device did not detect hydrocarbons concentration. The highest average of hydrocarbon concentrations was at Allhais which was recorded as 995, 598.15, 418.7, 358.89 and 279.13 ppm for methane, ethane, propane, butane and pentane respectively. The lowest average was found at the majnoon oil field for methane, ethane, propane, butane and pentane 395, 238.8, 167.16, 142.2 and 111.4 ppm respectively. The relationship between the average hydrocarbon concentrations with the average monthly wind speed and with average monthly temperature was positive.

Keywords. Power plant, Flaring gas, Hydrocarbons, Basra, Air pollution, Oil industries.

1. Introduction

Natural gas is regarded as one of the most efficient fuels. It is one of the non-renewable energy sources whose quantities diminish over time due to their widespread use [1]. The main Composition of natural gas is methane, Over one-third of all methane emissions resulting from human activity are produced by fossil fuel operations. Nearly 5% more methane was released into the atmosphere in 2021 as a result of the burning of fossil fuels, totaling approximately 120 Mt [2]. Natural gas contains a large quantity of methane with other hydrocarbons such as ethane, propane, etc and other non-hydrocarbons such as Carbon dioxide, Nitrogen, Hydrogen sulfide, Helium and some compound found in trace amounts [3].In 2020, Iraq was ranked 11th among the countries in the world's natural gas reserves [4]. The total proved reserves of natural gas in Iraq is 3.5 trillion cubic meters, with the production of 10.5 billion cubic meters (excludes gas flared or recycled. Includes NG produced for gas-to-liquids transformation) and produced oil 202 million tons in the same year [5].

Petroleum deposits typically contain a gaseous component known as "associated gas". If associated gas is not collected or used on-site, it may be flared or vented as a byproduct of oil production. Flaring is preferential to venting in terms of global warming. Flaring oxidizes carbon and produces CO_2, but by destroying methane and other hydrocarbons, it decreases the overall risk of global warming emissions. On a 100-year time scale, fossil methane is 36 times more potent than CO_2 [6]. [7] evaluated methane emissions from older light oil and natural gas production sites in Alberta, Canada at 60 measured sites. They found Three-quarters of the methane produced by oil and gas production is emitted by 20% of the sites. [4] studied the impact of natural gas flaring on air pollution and climate change in Basra According to the findings of their study, burning natural gas in Basra contributes to modifying the local climate by adding heat and greenhouse gases to the atmosphere, resulting in a rise in the region's air temperature. It has reached (52 degrees Celsius) in recent years, and it also influences air pollution by raising concentrations of harmful substances in the atmosphere. There was also a clear association between higher gas consumption and an increase in cancer incidence [4].

In this study, LEL was measured for selected gas flaring sites in Basra province. The Lower Explosive Limit (LEL) is the explosion range in which a gas's concentration explodes if an ignition source is brought close to it [8]. LEL is a critical metric for calculating the flammability and explosibility of flammable gases [9]. The hydrocarbons, like propane, and butane, have low explosive limits and high explosion risk indices [10]. The result showed that the hydrocarbons were found in all stations, in all measurements with different concentrations. The highest average hydrocarbon concentrations were found in Allhais, where the concentrations of methane, ethane, propane, butane, and pentane were their values ranged from 995 ppm to 279.13 ppm. While the lowest values were recorded in the Majnoon degassing station. The average monthly wind speed and temperature were positively correlated with the average hydrocarbon concentrations.

1.1. Study Area

The province of Basra is situated at latitude 30° N and longitude 047° 48 59 E in the southern region of Iraq. It shares international boundaries with the Arabian Gulf in the south, Kuwait in the southwest, and Iran in the east, as well as the provinces of Maysan and DhiQar in the north, Muthanna in the west. It occupies an area of 1973 km2, as depicted in figure (1) winters in Basra are cold and dry, and Summers are long and hot. The average annual temperature ranges from 7.2 °C to 46.6 °C, with recent years seeing temperatures above 50 °C [11]. In Basra, measurements were taken at six oil fields (Altuba, Allhais, Artawi, North Rumaila, Nahran omar, and Majnoon) and two power plants (Alnajebia power plant and Shatt AlBasra) fig. (1). All these stations are flaring gas.

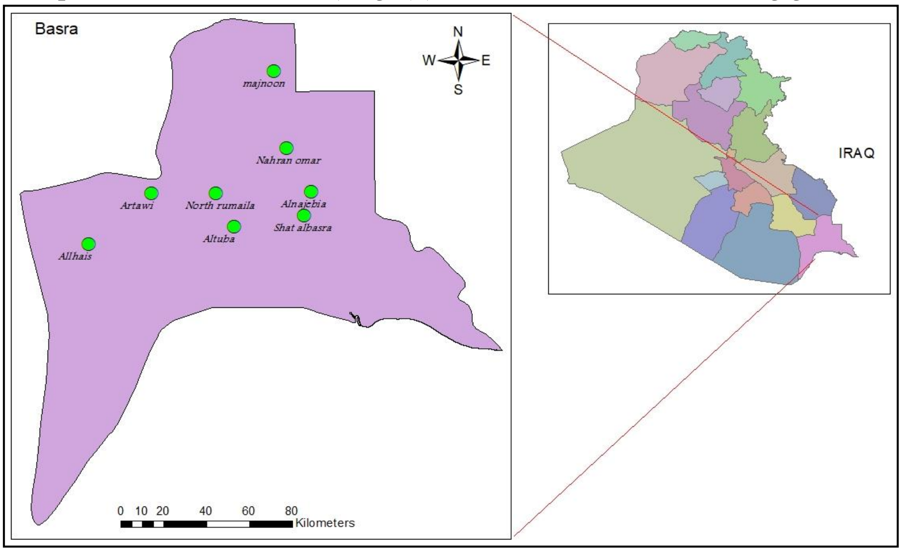

Figure 1. Study area.

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2. Materials and Techniques

Data were obtained from the six oil fields and the two power plants, mentioned in the study area, which were directly measured over six months using high-quality gas sensors (wintact device). The following calculation was used to convert LEL to hydrocarbons (methane, ethane, propane, butane, and pentane) at ppm**.** [12]

CH_4 (ppm) = LEL* 0.05*10000 C_2H_6(ppm) = LEL *0.03 *10000
C_3H_8(ppm)= LEL*0.021 *10000 C_4H_{10}(ppm)= LEL* 0.016*10000
C_5H_{12}(ppm)=LEL*0.015*10000

Air velocity meter and thermometer devices were used to measure wind speed and direction and air temperature on site.

By using a WR plot, wind speeds and directions were plotted as the wind rose.

The results were analyzed using the ANOVA test at $p \leq 0.05$ to show the significant variation and correlation coefficient between hydrocarbon concentrations, wind speed and temperature. The statistical calculation was carried out by SPSS V.29.

3. Result and Discussion

The rate of pollution dispersion is influenced by atmospheric stability. The degree of stability of the atmosphere must be known to estimate the ability of the atmosphere to disperse pollutants.

The Pasquill-Gifford stability classes [13] range from A to F depending on wind speed as shown in the table below [14].

Table 1. The Pasquill-Gifford stability classes range from A to F depending on wind speed.

Class	A	B	C	D	E	F
Description	Very unstable	Unstable	Slightly Unstable	Neutral	Slightly stable	Stable

Through our observation of wind speed and direction, during the period of measurement, which are depicted in Figure (2) in the form of a wind rose, we were able to determine the type of stability of the atmosphere, which influences the spread of gases and pollutants in the atmosphere as shown in Table (2).

Table 2. Atmospheric stability for each station and its measurements.

Stations	Measurement					
	1	2	3	4	5	6
Nahran Omar	C	C	D	C	C	C
Altuba	C	D	C	D	D	D
Allhais	C	C	D	D	C	B
Artawi	B	C	C	D	C	C
Alnajebia	C	D	D	C	C	A
Shatt AlBasra	C	D	C	D	D	C
North Rumaila	B	B	D	D	B	D
Majnoon	D	C	D	D	D	C

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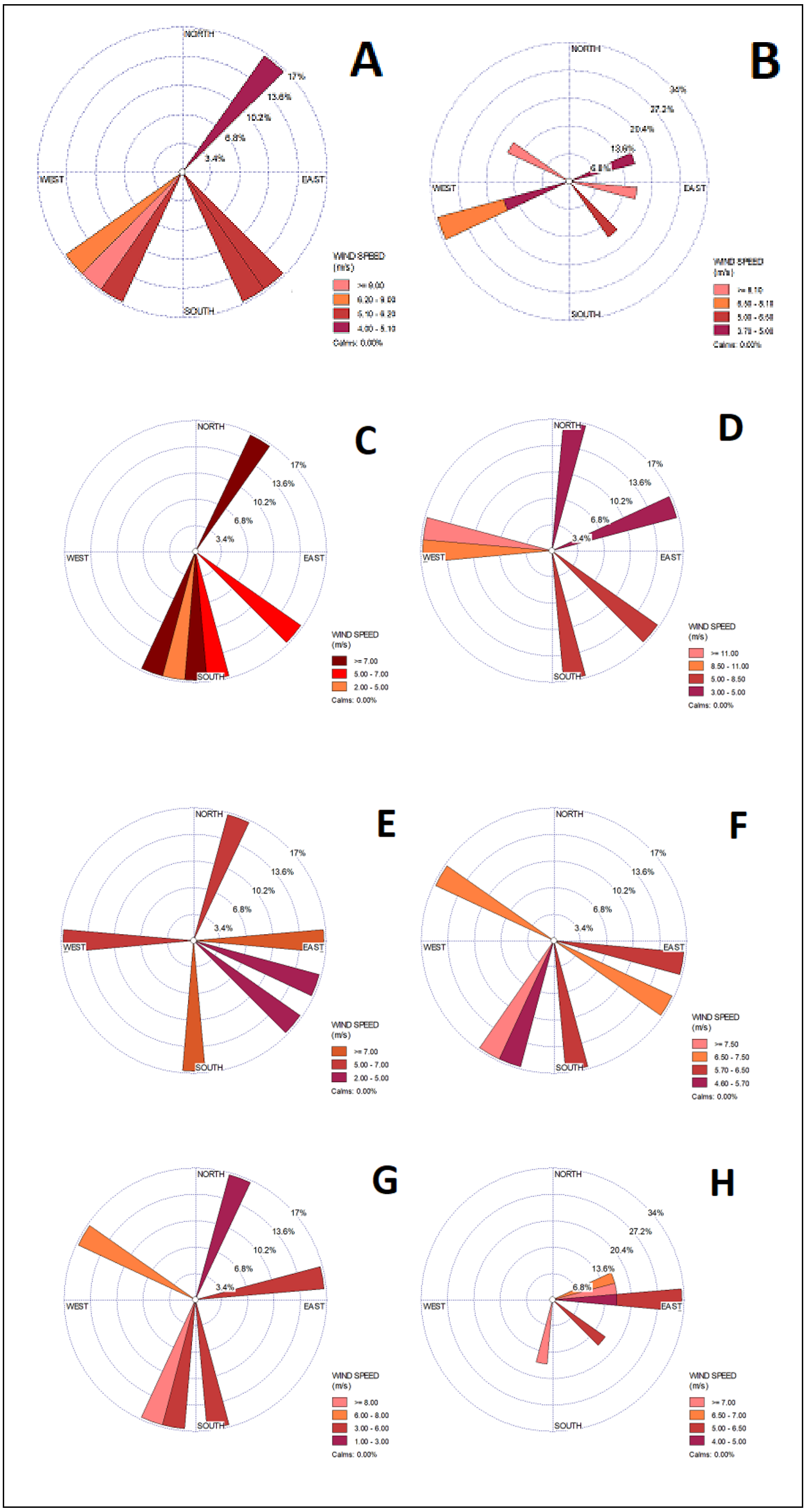

Figure 2. Wind rose for all stations and measurements, letters A, B, C, D, E, F, G, and H represent stations (Nahran omar, Altuba, Allhais, Artawi, Alnajebia, Shatt al Basra, North Rumaila, Majnoon) respectively.

3.1. Variation in HC Concentrations

Methane, ethane, propane, butane, and pentane are all hydrocarbons that are potent greenhouse gases when released into the atmosphere. When these gases are burned, they produce carbon dioxide and water vapor, which contribute to global warming. In this study, we measured the highest five percentages of natural gas components.

LEL was measured during six measuring months as shown in table (3). LEL ranged from 0.13% to 3%. The lowest value of LEL (0.13%) was at North Rumaila at the second measurement. The highest value of LEL (3%) was at Allhais at the sixth measurement, this was because of several parameters: intensity of pollutant emissions, meteorological parameters, gas production activities, the height of the flares, distance from the source, the efficiency of emissions mitigation strategies and speed of emission.

Table 3. LEL measuring in percentage.

Stations	Measurements						Average LEL in the stations
	1	2	3	4	5	6	
Nahran Omar	0.366	1.76	0.466	2.16	2.2	1.9	1.47
Altuba	1.266	0.33	0.33	1.7	1.266	1.533	1.07
Allhais	2.033	1.4	1.4	1.9	2.33	3	2.01
Artawi	0.833	1.43	1.43	2.2	1.86	1.96	1.61
Alnajebia	0	1.5	1.2	2.36	1.6	1.56	1.644
Shatt AlBasra	0	2.33	2.03	2.33	1.5	1.53	1.944
North Rumaila	0.433	0.13	1.36	1.1	1.2	0.66	0.95
Majnoon	1.33	0.45	0.533	1.2	0.733	0.53	`0.79

In this study, methane was too lean to explode but the other measured gases were in the explosive range as shown in table (4). Ethane exceeded the lower explosive limit in allhais at the sixth measurement. Propane was in the explosive range at the second measurement in Shatt AlBasra, and at the fourth measurement in Nahran Omar, Artawi, Alnajebia and Shatt AlBasra, and at the fifth measurement in Nahran Omar and Allhais. Butane was recorded at the first measurement in allhais, at the second measurement in Nahran Omar and Shatt AlBasra, at the third measurement in Shatt AlBasra, at the fourth measurement in all stations except North Rumaila and majnoon, at the fifth measurement in Nahran Omar, Allhais, Artawi and Alnajebia, and at sixth measurement in Nahran Omar, Allhais and Artawi. Pentane was more than other gases at risk of explosion. it was exceeded the lower explosive limit at the first measurement in allhais, at the second measurement in Nahran Omar, Alnajebia and Shatt AlBasra, at the third measurement in Shatt AlBasra, at the fourth measurement in all stations except North Rumaila and majnoona, at fifth measurement in all stations expect Altuba, North Rumaila and majnoona, and at sixth measurement in all stations expect North Rumaila and majnoona.

Table 4. Lower and Upper explosive limit for study gases [12].

Gas	LEL	UEL
Methane	5	15
Ethane	3	12.5
Propane	2.1	9.5
Butane	1.6	8.4
Pentane	1.5	7.8

To demonstrate the quantity of concentration of gases that were not burned, LEL was transformed to methane, ethane, propane, butane, and pentane. The highest average concentrations of these gases were discovered during the fourth measurement, and they were 934.37, 560.62, 392.43, 336.37, and 261.62 ppm, figure (3) A, B, C, D,E) respectively. During all these measurements, the dominated stability class D table (1). Because the atmosphere is mainly neutral, it does not assist or oppose the vertical motion which means the pollutants do not mitigate. Any effluent that is discharged into the atmosphere tends to produce a cone-shaped plume. Therefore, if the emission source is close to the ground, it could settle on the ground, but if the emission source is highly elevated, it will not contribute to considerable pollution on the ground. The lowest average of methane, ethane, propane, butane and pentane concentrations found during the first measurement was 521.75, 313, 219.13,187.83, 146.09 521.75 figure ((3)A, B, C, D, E) respectively. At this measurement, the most frequent stability was class C followed by class B (table (1)). At this condition of stability, the pollutant was mixed by enhanced upward motion and led to dilution and dispersion more than in the neutral stability [14,15].

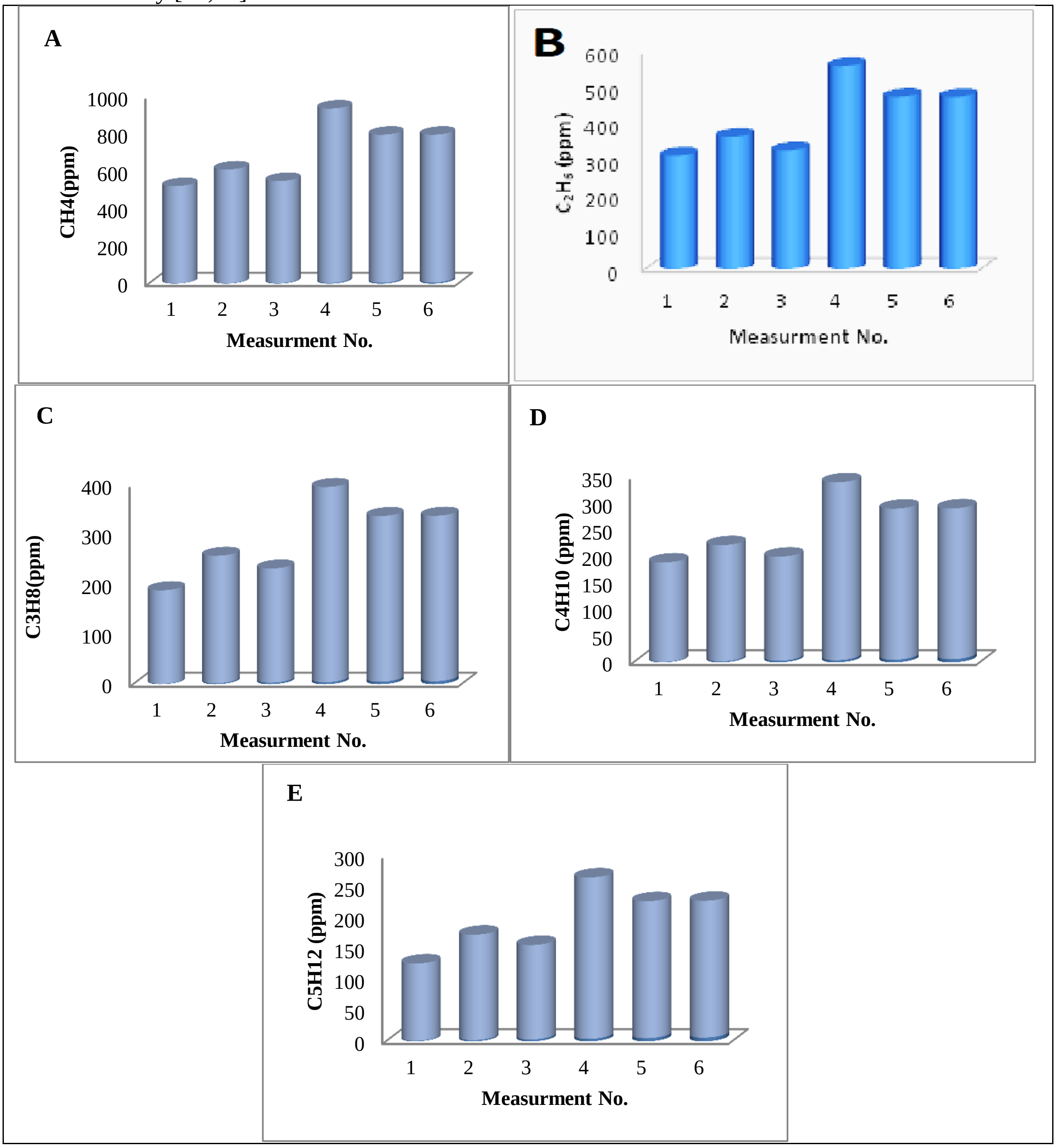

Figure 3. The average concentration of hydrocarbons in each measurement, letters (A, B, C,D,E) represent methane, ethane, propane, butane, and pentane respectively.

There is a statistically significant difference between the measurements (p-value = 0.02), so we reject the null hypothesis (the hypothesis proposed that all measurements are equal) therefore, the alternative hypothesis is accepted (it assumed that measurements are not equal).

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3.2. Spatial Variation in HC Concentrations

The highest average concentration of gases was at Allhais Degassing station recorded at 995, 598.15, 418.7, 358.89, and 279.13 ppm figure ((4) A, B, C, D, E) for methane, ethane, propane, butane and pentane respectively. Because of the inefficiency of the flares located in these stations, as they did not burn the gas completely and the second reason could be the inappropriate height of the flares which was 4 m. Sayar and Jozaei [16] show in their study the concentration density of pollutant was decreased when the flared high was increased. In the current study, the lowest average concentration was at Majnoon oil field, it recorded 395, 238.8, 167.16, 142.2 and 111.4 ppm figure ((4) A, B, C, D, E) for methane, ethane, propane, butane and pentane respectively. The location of the measuring at Majnoon oil field was farther from the flares compared with other study stations and for this reason recorded the lowest concentration of gases.

The result was statistically significant and indicated a significant variation (p = 0.03) among the average concentrations of methane, ethane, propane, butane, and pentane in the stations.

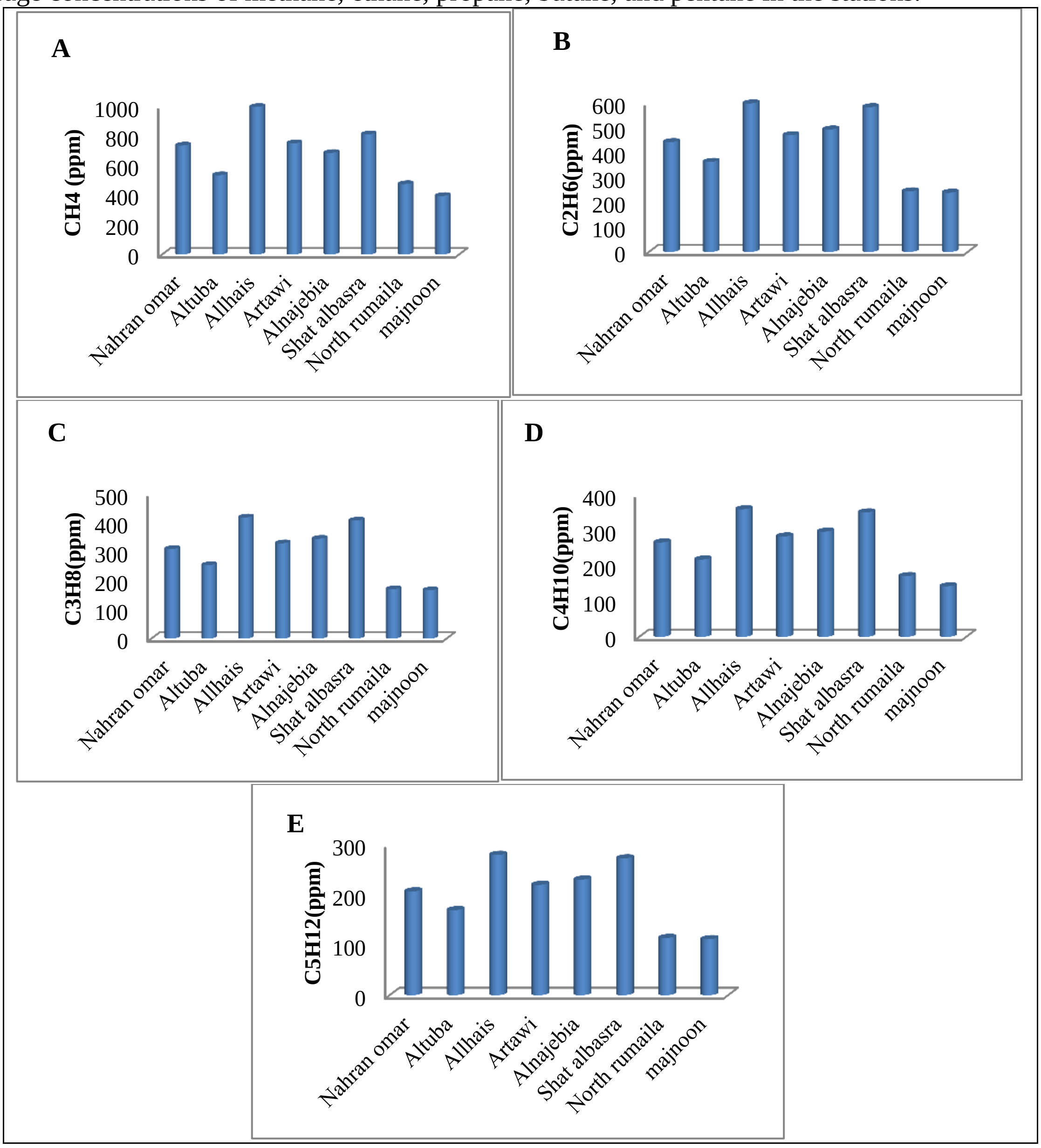

Figure 4. The average concentration of hydrocarbons in each station, letters (A,B,C, D,E) represent methane, ethane, propane, butane,and pentane respectively.

3.3. Temperature

The temperature was recorded by using a velocity meter device at Celsius degrees for all stations in all measurements as shown in table (5) to show the relationship between temperature and the pollutant result from flaring gas. the average temperature was 18.07,20.22,39.03,42.64,45.36 and 45.22 °C for the first, second, third, fourth, fifth, and sixth measurements respectively.

Table 5. The temperature in all stations for all measurements.

Stations	Measurements in °C						Correlation coefficient
	1	2	3	4	5	6	
Nahran Omar	18.8	24.1	37.2	42	47	41.3	0.62
Altuba	17.9	19	36.5	38.6	44	40	0.4
Allhais	17.8	18.6	40.3	48.9	50.9	52.1	0.39
Artawi	18.4	20	42.1	49.2	51.3	53.5	0.83
Alnajebia	21.3	18.7	38.7	42	42.8	44.5	0.6
Shatt AlBasra	17.77	19	38.5	40.6	42	45.7	0.45
North Rumaila	15.75	22	40	39.4	41.4	43.7	0.91
Majnoon	16.89	20.4	39	39.8	43.5	41	- 0.18

The relationship between temperature and concentrations of gases was quantified using the Spearman correlation. The correlation coefficient in all the stations was positive and the value ranged from 0.39 to 0.91, except the value in Majnoon the correlation, was negative and weak, its value is -0.18.

Conclusions

In conclusion, the study found high concentrations of hydrocarbons in gas-flaring areas due to incomplete combustion, with varying concentrations between stations and measurements based on several factors. The majority of gases exceeded the lower explosive limit, posing a risk of explosions. The fourth measurement had the highest average concentration of hydrocarbons due to neutral atmospheric stability. The study identified a positive correlation between temperature and gases, except for in Majnoon, which had a weak negative correlation. These findings emphasize the importance of implementing effective emissions control strategies and conducting further research on the impact of gas flaring on the environment and human health.

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