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Trends in Air Pollution in the Middle and South of Iraq: As Climate Change Evidence in the Region

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Abstract. Changes in climatic circumstances brought on by climate change could influence air pollution and finally harm the ecosystem and human health. From January to December, central and southern Iraq saw air quality and climate indicators in 2021 and 2024. Temperatures increased in 2024 compared to 2021, especially in Maysan city, where they hit about 52°C. Furthermore, yearly variation in wind speed is possible; relative humidity was maximum in 2024 in Baghdad City at 58.4. Air pollution levels of CH_4 in Wasit City peaked in 2024, above those noted in 2021, at 1923.34 ppmv. Moreover, 2024 saw the highest NO_2 level in Baghdad city at 158.553 µmol/m^2. The PCA and correlation studies indicated a positive association between CO, and NO_2 with wind speed, implying that these gases in the atmosphere of central and southern Iraq are influenced by wind speed. Moreover, O_3 and temperature have unfavorable connections, implying that these factors could influence the level of O_3 in the atmosphere.
Keywords: air pollution, meteorological, Iraq, PCA and correlation

INTRODUCTION

In recent years, air pollution has become one of the most important health concerns in Iraq [1]. This invisible killer lurking in our environment affects the young as well as the old. According to the World Health Organization, 7 million people die annually as a result of air pollution [2]. Furthermore, the world climate is affected by air pollution and it greatly changes atmospheric composition [3]. Ambient air pollution includes both gaseous pollutants and particulate matter (PM2.5 and PM10) [4]. Urban regions experience elevated air pollution levels due to anthropogenic activity, particularly the combustion of fuels in transportation and industry, alongside the dispersion of airborne particulates. These pollutants disperse extensively from their origin into the atmosphere, where they may persist for hours or even many days, contingent upon the prevailing meteorological conditions [5]. Consequently, anthropogenic activities generate substantial amounts of greenhouse gases, which contribute to global warming and lead to considerable environmental damage. Therefore, it is very important to focus on the gases emitted from various human sources in Iraq, which have led to many human diseases and air pollution in particular.

Various research examines air pollution in Iraq, such as [6], which investigate air pollution levels adjacent to roadways in Baghdad, Iraq. [7] demonstrated the impact of industrial activities on air pollution in Baiji. [8] evaluated the health effects of air pollutants in five Iraqi cities. Using Sentinel-5P data and the GEE platform, [9] evaluated the coronavirus pandemic's impact on tropospheric nitrogen dioxide and carbon monoxide levels. Moreover, [10] conducted a comparative investigation of the spatial distribution of tropospheric nitrogen dioxide (NO_2) columns above Tehran under pandemic and normal conditions, utilizing data from the European Space Agency (ESA) Copernicus Sentinel-5P products.

Though some research looked at the temporal and spatial patterns of pollutant levels in certain areas of Iraq, the relationship between air pollution and multi-scale meteorological conditions and their spatial fluctuations in the middle and south of Iraq still unknown. Therefore, the objectives of this study are to assess the meteorological conditions in the middle and south of Iraq and to evaluate the temporal distribution of air quality from 2021 and 2024.

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MATERIALS AND METHODS

Study area

Located in West Asia, Iraq is notable geographically. Its latitude is 33° 13' 15.34" N, and its longitude is 43° 41' 5.13". It is bordered by Saudi Arabia to the south, Turkey to the north, Iran to the east, Kuwait to the southeast, Jordan to the southwest, and Syria to the west. With a population of about 7,216,040, Baghdad, the capital of Iraq, is the biggest city in the nation [11].

Iraq has a dry and semi-arid climate, marked by hot summers and cold winters.

From October to May, precipitation occurs; the northeast sees the most rain and the southwest the least. Recent years have seen Iraq suffer recurrent major droughts ascribed to recorded low rainfall and significant warming trends [12]. From north to south, the main sources of anthropogenic pollution in Iraq are oil refinery plants, textiles, rubber, and food [13]. Air quality in the main governorates of central and southern Iraq—including Baghdad, Karbala, Babil, Wasit, Al-Qadisiyah, Najaf, Maysan, Dhi-Qar, Muthannia, and Basrah—was investigated in the study Fig. 1.

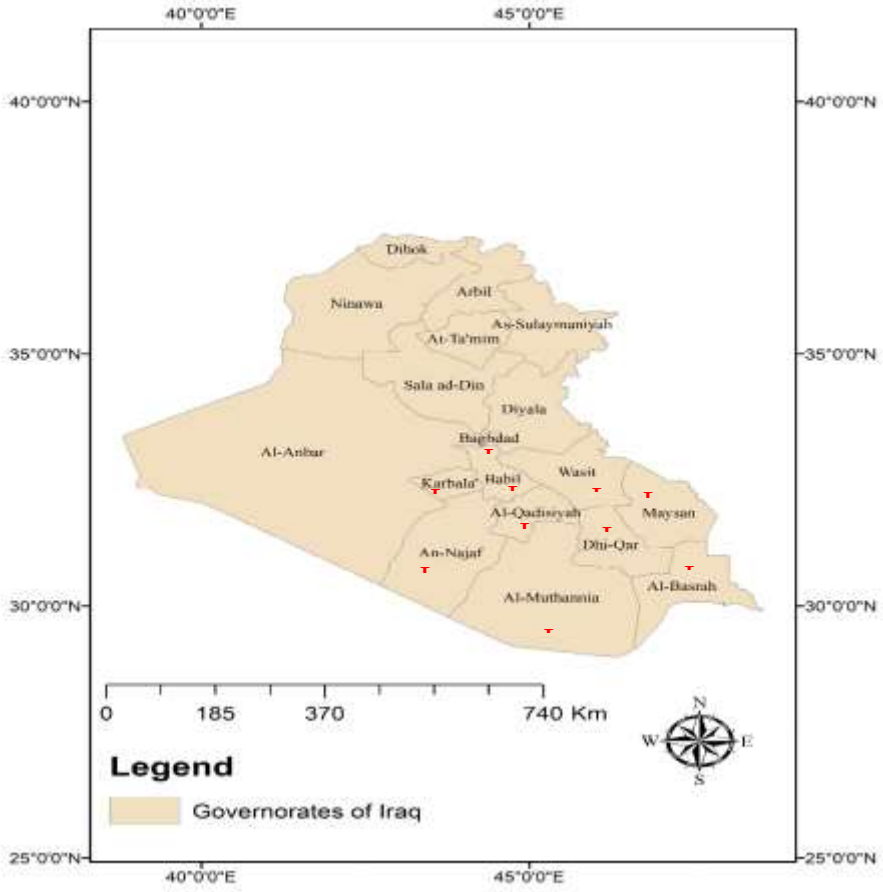

FIGURE 1. Iraq map and data measurement over middle and south of Iraq

Source of air pollution data

From Sentinel-5P Data (European Commission/ESA/Copernicus), the air pollution data in central and southern Iraq were taken in each governorate (Fig. 1). This data was gathered to quantify the concentrations of CH_4, O_3, CO, HCOH, and NO_2 in designated study locations in Iraq via the TROPOMI Explorer application, covering the years 2021, and 2024 in middle and south of Iraq. The years 2021 and 2024's data on humidity, temperature, and wind speed and direction came from source https://power.larc.nasa.gov/data-access-viewer.

Statistical study

Air quality indicators and meteorological conditions in central and southern Iraq were evaluated using principal component analysis (PCA) run on SPSS 25.0 (International Business Machines Corporation, USA) together with the Pearson correlation coefficient (r), a statistical technique for quantitatively describing and examining the correlation between several variables. [14]

RESULTS AND DISCUSSION

Weather data

Meteorological conditions significantly influence air quality by regulating the movement, transformation, and dispersion of pollutants in the atmosphere. The following are the key factors:

Wind factor

The figures show the daily average wind speed and direction for the years 2021 and 2024 as shown in Table 1, 2.

The wind directions show that the predominant wind direction in Baghdad during October (343.5°), and April (356.2°) corresponds to the years 2021, and 2024, respectively. The main wind direction at Karbala in July (328.56°) and November (336.1°) corresponds to 2021 and 2024, respectively. The prevailing wind direction at Wasit between October (333.38°) and May (335°) corresponds to 2021 and 2024, respectively. Najaf's predominant wind direction in June (340.19°) and November (326.2°) matches 2021 and 2024, respectively. The prevailing wind direction at Maysan for November (340.19°) and May (312.5°) matches 2021 and 2024, respectively.

July saw the highest wind speeds in Baghdad, with 2.62 and 2.98 meters per second in 2021 and 2024, respectively. The significant wind changes happening over the summer season affect the acceleration rate of the wind, which explains these figures. Moreover, Wind speeds in Basra hit their maximum peak in July, with readings of 5.7 meters per second in 2021 and 5.1 meters per second in 2024. The findings of this study agree with those of a study done by [1] in the oil fields of Basra city.

The wind speeds reported at Muthanaa city for June 2021 and 2024 were 4.09 meters per second as contrasted to 3.77 meters per second in the same month. The wind speeds at Maysan also peaked in June at 5.76 meters per second and in July at 4.81 meters per second in 2021 and 2024, respectively. The higher wind speeds seen during the summer months may be caused by the seasonal winds called the Sharqi, which are usually described as having high humidity and high temperatures. Dhi Qar's wind speed peaked at 5.32 meters per second in June 2021 and again at 4.8 meters per second in July 2024. The seasonal winds called the Sharqi, which are often hot winds and heavy humidity, may explain the increased wind speeds during these summer months. For 2021, the wind speed in Dhi Qar was greatest on June 5.32 m s− 1; for 2024, it was 4.8 m s− 1. The distribution and concentration of air contaminants are greatly influenced by wind velocity. Minimal wind speeds cause air to stagnate. Contaminants gather near their source, increasing local concentrations. Therefore, important factors influencing the spread and transportation of air pollutants include wind speed and direction [15].

TABLE 1. The following table shows the weather data for central and southern Iraq for WD in the years 2021, and 2024.

Baghdad	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	288.25	330	283.06	319.19	306.31	317.25	318.44	311.62	318.19	343.5	339.44	297.81
WD 2024	286.1	321.6	277	356.2	316.5	320.5	307.8	308.4	315.8	325.9	331.1	322.8
Karbala	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	289.19	313.44	281.44	319.75	316.44	328.75	328.56	321	326.06	352.5	327.06	302.38
WD 2024	278.3	301.7	281.4	331.3	318.9	322.7	315.7	317.1	322.1	332.5	336.1	316.4
Babylon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	284.69	314.75	288.56	321.06	305.56	322	322.94	315.69	320.5	341.62	322.31	298.56
WD 2024	286.7	302.5	280.9	328.8	318.6	318.9	312.8	312.5	317.1	322.3	328.3	313.7
Qadisiyah	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	286.56	314.38	300.81	322.56	306.69	322.62	324	321.25	321.62	338.62	320.12	304
WD 2024	293	302.9	285.1	331.1	326.7	320.1	312.5	314.2	319	320.1	322.6	310.1
Wasit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	295	315.56	318.38	325.69	308.56	320.88	322.25	322.69	321.88	333.38	323.38	308.31
WD 2024	304.7	315.2	302.9	3.5	335	324.8	313.5	315.5	320	319.1	320.6	314.3
Maysan	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	299.25	305.81	308.62	310.25	301.56	307.25	306.5	313.56	307.81	314.81	316.88	309.06
WD 2024	292.2	295.3	283.1	2.3	312.5	299.2	292.9	294.6	297.6	294.1	291	299
Dhi Qar	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	291.06	306.5	312.12	317.94	304.31	317.5	318.69	321.81	318	324.62	316.88	303.5
WD 2024	295.9	299	289.3	296	325.2	314.2	309.6	311.5	314.6	307.8	311	296.4
Muthannia	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	285.56	306.31	301.69	322.31	308.69	326.12	325.88	323.12	324.75	341.19	316.56	298.38
WD 2024	287.6	299.1	282.2	319.5	319.2	319.4	314.6	314.8	318.7	321.8	326.2	309.3
Basra	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	294.06	310.12	310.06	306.06	302.56	312.38	310.88	310.75	314.69	316.25	310.56	291.94
WD 2024	300.7	300.7	288.2	268.8	315.7	303.2	305.2	303.1	306.4	299.2	310	296.5
Najaf	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WD 2021	279.88	319.94	285.75	335.25	318.56	340.19	338.19	328.19	336.81	54.69	339.75	301.69
WD 2024	287.6	299.1	282.2	319.5	319.2	319.4	314.6	314.8	318.7	321.8	326.2	309.3

TABLE 2. The following table shows the weather data for central and southern Iraq for WS in the years 2021, and 2024.

Baghdad	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	1.57	1.53	1.8	1.97	2.03	2.82	2.62	2.11	2.27	1.85	1.69	1.72
WS 2024	1.67	1.66	1.79	1.86	1.85	2.43	2.98	2.54	2.24	1.67	1.67	1.72
Karbala	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.34	2.25	2.88	2.87	2.88	3.73	3.57	2.83	3.05	2.27	2.43	2.5
WS 2024	2.32	2.66	2.82	2.83	2.75	3.64	4.19	3.41	3.16	2.42	2.38	2.48
Babylon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	1.94	1.88	2.29	2.5	2.37	3.55	3.29	2.54	2.72	2.05	2.01	2.15
WS 2024	2.02	2.15	2.28	2.38	2.32	3.33	3.76	3.08	2.75	2.09	2.08	2.19
Qadisiyah	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.13	2.23	2.58	3.03	2.61	4.37	3.86	2.97	3.34	2.43	2.35	2.51
WS 2024	2.4	2.35	2.53	2.75	2.66	3.86	4.36	3.67	3.25	2.46	2.6	2.52
Wasit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.05	2.38	2.7	3.35	2.66	5.14	4.38	3.37	4.09	3.01	2.36	2.67
WS 2024	2.64	2.26	2.46	2.64	2.77	3.8	4.81	4.26	3.78	2.63	2.89	2.58
Maysan	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.12	2.53	2.95	3.43	2.93	5.76	4.68	3.58	4.38	3.3	2.3	2.61
WS 2024	2.3	2.34	2.51	2.38	2.94	3.43	4.81	4.16	3.67	2.52	2.42	2.04
Dhi Qar	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.21	2.61	2.9	3.52	2.87	5.32	4.34	3.43	4.11	2.93	2.48	2.62
WS 2024	2.67	2.68	2.73	2.96	2.93	4.08	4.8	4.1	3.67	2.71	2.82	2.75
Muthannia	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.25	2.35	2.67	3.11	2.53	4.09	3.48	2.8	3.12	2.19	2.55	2.59
WS 2024	2.07	2.19	2.36	2.5	2.41	3.46	3.77	3.04	2.69	2.12	2.15	2.26
Basra	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.73	3.16	3.45	3.71	2.96	5.7	4.19	3.45	4.32	3.28	2.7	2.91
WS 2024	3.13	3.17	3.21	3.21	3.55	3.7	5.12	4.3	4.02	2.94	3.23	2.97
Najaf	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WS 2021	2.21	2.53	2.79	2.66	2.58	3.04	3.04	2.61	2.52	2.26	2.31	2.31
WS 2024	2.07	2.19	2.36	2.5	2.41	3.46	3.77	3.04	2.69	2.12	2.15	2.26

Temperature factor

As shown in Table 3, the figures show the daily temperatures for the years 2021 and 2024. Iraq's governorates, made up of 10 central and southern areas, had temperatures for the years 2021, and 2024. In June 2021, the greatest temperature noted in Baghdad Governorate was 50.76°C; in June 2024, it was 50.83°C. The Qadisiyah Governorate also noted a temperature of 51.87 degrees Celsius in June 2021 and 51.83 degrees Celsius in June 2024. In July 2021, the Basra Governorate's maximum temperature was 51.43 degrees Celsius. Dhi Qar's July 2021 temperature reached 52.5°C. The temperature hit 51.64°C in August 2024. While in 2024, the highest temperature was recorded in June at 51.16°C, the Babylon Governorate had a peak temperature recorded in 2021 at 51.24°C in July. In Wasit Governorate, the temperature peaked in July 2021 at 51.74°C. The highest recorded temperature in 2024 was 50.75°C in June. August 2021 saw the highest recorded temperature in Maysan Governorate at 50.57°C. The highest temperature noted was 52.27 degrees in July 2024. The highest temperature recorded in July was 52.37. The highest temperature noted in

Muthannia Governorate in July 2021 was 50.62 degrees. The highest temperature in June 2024 was 51.23 degrees. The maximum temperature recorded in Najaf Governorate in June 2021 was 48.32 degrees. The highest temperature in 2024 was 51.23 degrees. The temperature was higher in June. The highest rise in Karbala Governorate in August 2021 was in June at 49.05°C; in 2024, it reached 49.31°C. Insufficient plant cover causes higher temperatures, which changes the region into an arid desert and causes dust storms. Many studies have looked at vegetation-based methods to improve local thermal comfort in urban settings. Extensive studies have been done on how trees affect solar transmissivity [16] and how shade affects thermal comfort [17]. The literature records the effects of different plant infrastructures on local microclimates, such as vertical greenery[18], and the impact of the arrangement of vegetation components [19][20][21][22]. Temperature affects pollution emissions and the surface retention of contaminants, hence influencing air quality. In Iraqi governorates, higher emissions from natural and anthropogenic sources could significantly influence temperature increases.

TABLE 3. The following table shows the weather data for middle and south Iraq for temperatures in the years 2021, and 2024.

Baghdad	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	22.32	28.58	30.37	42.64	46.1	50.76	50.46	49.6	48.78	42.86	35.33	24.43
Temp(Min_2021)	-1.67	0.99	5.38	9.63	20.92	23.29	27.65	25.81	19.26	13.65	9.34	0.3
Temp(Max_2024)	25.15	25.99	31.67	40.86	47.19	50.83	50.65	49.1	49.27	40.43	29.94	22.25
Temp(Min_2024)	3.02	2.14	3.49	12.87	15.09	24	29.08	27.52	20.94	9.97	2.46	-0.32
Karbala	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	21.14	27.74	30.33	40.98	44.09	49.05	48.14	47.26	47.4	41.02	34.42	22.99
Temp(Min_2021)	-1.03	2.84	6.34	10.62	21.03	23.88	26.75	26.84	20.32	16.38	9.11	0.82
Temp(Max_2024)	23.44	24.25	29.25	39.7	46.38	49.31	48.65	47.25	47.18	39.05	29.33	22
Temp(Min_2024)	4.03	3.58	2.96	14.03	16.52	25.61	28.96	28.11	21.82	11.32	5.09	0.25
Babylon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	23.17	29.12	32.08	42.73	45.15	51.05	51.24	49.95	49.08	42.97	35.8	25.6
Temp(Min_2021)	-1.8	2.31	5.73	10.05	21.15	24.13	27.78	26.23	20.08	15.3	8.78	0.5
Temp(Max_2024)	25.96	26.62	31.11	41.51	48.3	51.16	50.79	49.81	49.36	40.37	30.93	24.73
Temp(Min_2024)	4.11	3.03	2.23	13.55	16.03	25.5	29.38	28.23	21.49	10.88	4.15	-0.07
Qadisiyah	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	23.71	29.86	33.47	43.27	45.95	51.19	51.87	50.49	48.81	43.84	35.89	26.84
Temp(Min_2021)	-2.13	3.03	6.02	10.85	21.76	24.85	28.42	26.4	20.54	16.17	9.16	1.15
Temp(Max_2024)	27.8	27.53	33.89	41.43	48.44	51.38	50.77	50.6	50	40.84	34.06	25.24
Temp(Min_2024)	4.55	3.38	1.95	13.72	16.55	26.08	29.94	28.7	22.1	11.49	4.86	0.28
Wasit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	23.12	30.12	33.25	42.98	46.55	50.83	51.74	50.15	48.64	43.72	34.98	25.65
Temp(Min_2021)	-0.56	3.18	6.81	10.99	21.33	25.43	28.7	27.56	20.44	16.17	10.06	1.29
Temp(Max_2024)	25.96	27.05	33.27	41.12	48.03	50.75	50.33	50.3	49.29	41.16	34.79	25.73
Temp(Min_2024)	4.56	3.62	3.8	13.68	16.41	24.84	29.89	29.34	23.25	11.28	4.57	0.56
Maysan	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	24.69	31.69	37.16	43.03	47.58	50.48	52.27	50.22	49.12	44.48	36.15	27.02
Temp(Min_2021)	0.41	4.83	7.41	12.52	21.92	26.38	30.05	29.55	21.15	16.91	11.03	2.94
Temp(Max_2024)	25.61	26.92	33.21	40.67	48.91	51.3	52.37	51.59	49.4	41.15	35.83	26.68
Temp(Min_2024)	5.79	4.93	3.54	14.48	16.55	24.67	29.43	29.72	24.38	12.6	4.26	2.42

Dhi Qar	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	24.88	32.55	38.4	43.28	47.94	51.23	52.52	50.2	48.92	44.43	36.73	26.96
Temp(Min_2021)	-1.89	4.6	6.69	11.76	21.8	25.98	29.47	28.23	19.63	17.15	9.98	2.07
Temp(Max_2024)	28.66	28.56	34.39	40.97	48.92	51.46	50.97	51.39	49.5	42.02	36.11	27.63
Temp(Min_2024)	3.94	4.18	2.46	14.42	17.12	26.52	29.61	28.76	22.44	12.41	5.26	0.51
Muthannia	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	24.54	30.44	34.87	41.74	45.36	50.18	50.62	49.4	47.29	42.7	36.33	27.76
Temp(Min_2021)	-1.6	3.82	6.18	10.05	20.34	24.26	26.78	26.08	21.33	17.1	9.85	0.94
Temp(Max_2024)	26.26	26.64	31.37	41.23	48.46	51.23	50.73	50.25	49.32	40.92	31.59	24.84
Temp(Min_2024)	4.16	3.33	2.65	13.89	16.13	25.78	28.79	28.15	21.85	11.26	4.82	0.71
Basra	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	25.73	32.8	40.87	42.48	46.94	50.07	51.43	50.05	48.31	44.04	36.13	27.27
Temp(Min_2021)	0.19	6.07	7.9	12.8	22.59	26.88	30.15	29.2	21.13	18.11	11.56	2.45
Temp(Max_2024)	26.88	28.25	32.41	40.47	49.42	51.61	51.6	51.87	49.69	42.11	37.02	26.54
Temp(Min_2024)	5.39	5.71	4.09	14.29	17.52	27.72	31.16	31.08	24.5	13.78	5.53	2.82
Najaf	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp(Max_2021)	21.05	28.87	31.83	40.24	43.25	48.32	47.85	46.74	45.51	41.03	34.86	24.52
Temp(Min_2021)	-3.08	2.28	4.54	9.55	18.87	22.52	24.98	24.92	19.63	15.7	8.83	-0.19
Temp(Max_2024)	26.26	26.64	31.37	41.23	48.46	51.23	50.73	50.25	49.32	40.92	31.59	24.84
Temp(Min_2024)	4.16	3.33	2.65	13.89	16.13	25.78	28.79	28.15	21.85	11.26	4.82	0.71

Humidity factor

As shown in Fig 2, the figures show the daily humidity rates for 2021, 2024. In Iraqi governorates, humidity levels in the air varied with time and over several months. The highest relative humidity observed by Baghdad Governorate in February 2021 was 53.31%. Though the highest relative humidity was recorded in Maysan Governorate at 66.38% in January 2021, humidity in February 2024 hit 0.58%. The highest humidity in February 2021 was 54.44%; by February 2024, it had risen to 57.15. For 2021, Qadisiyah Governorate reached 53.94%. February saw the highest recorded humidity in 2024 with 55.85%. Wasit's highest humidity was 52.81% in 2021 and 56.69% in 2024. The humidity rate in Dhi Qar Governorate for January 2021, the greatest reported was 50%, while in 2024 it rose to 52.16%. In February 2021, the Muthannia Governorate had a maximum humidity of 50.25%; in February 2024, it was 54.61%. While the highest humidity of 54.61% was recorded in February 2024, the highest humidity of 53.25% was recorded in December 2021 in Basra Governorate. Humidity in Najaf Governorate climbed to 52.75% in February 2021 and to 54.61% in 2024. In 2021, Babylon Governorate saw an increase in humidity; it was 53.94%. The highest humidity rate in 2024 was 55.85% in February. A key component in the assessment of weather and climate is atmospheric humidity, which influences temperature, ozone production, and changes in airborne particle concentration [1]. Humidity significantly increases heat-related discomfort and influences airborne transmission [23][24].

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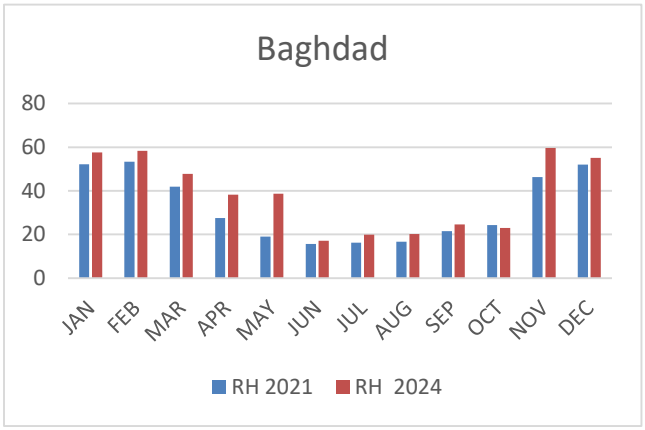

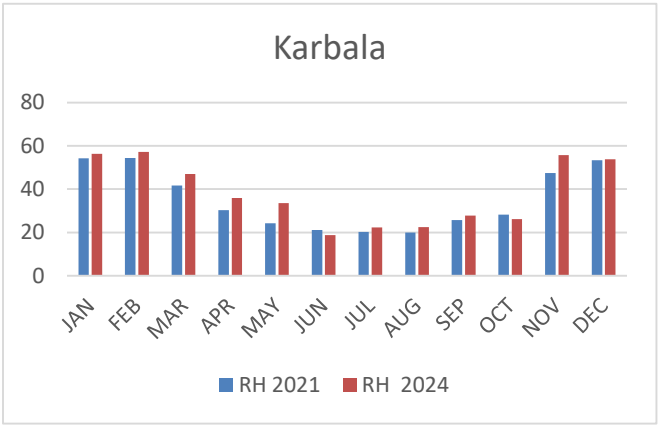

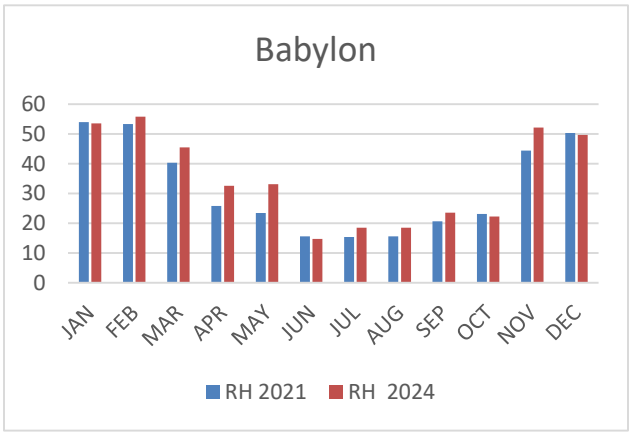

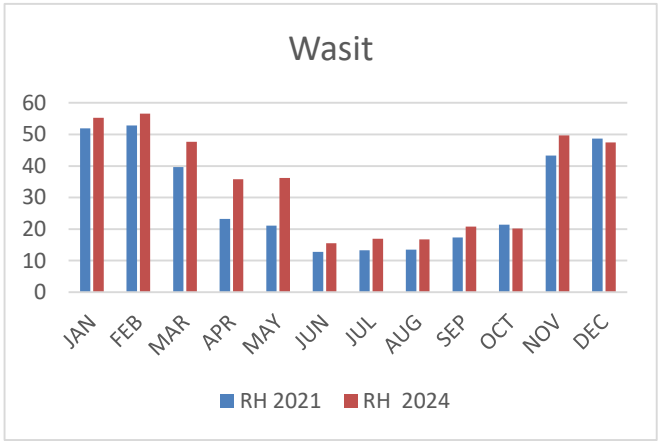

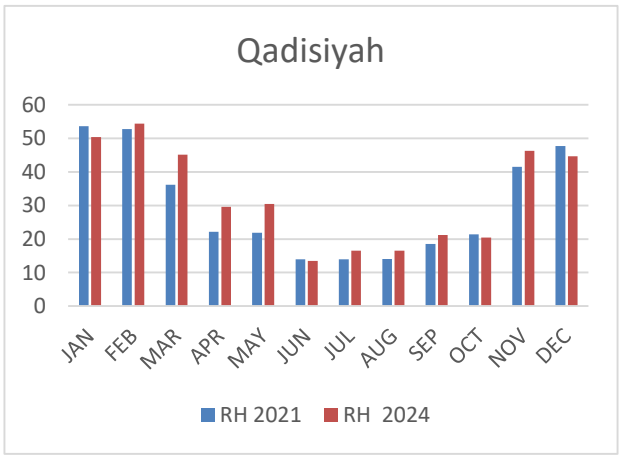

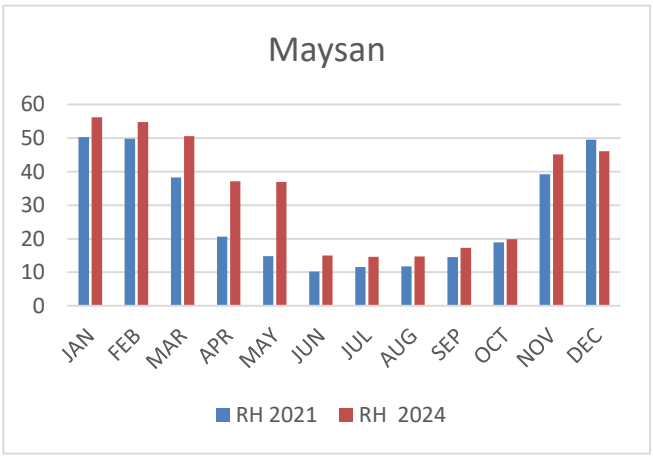

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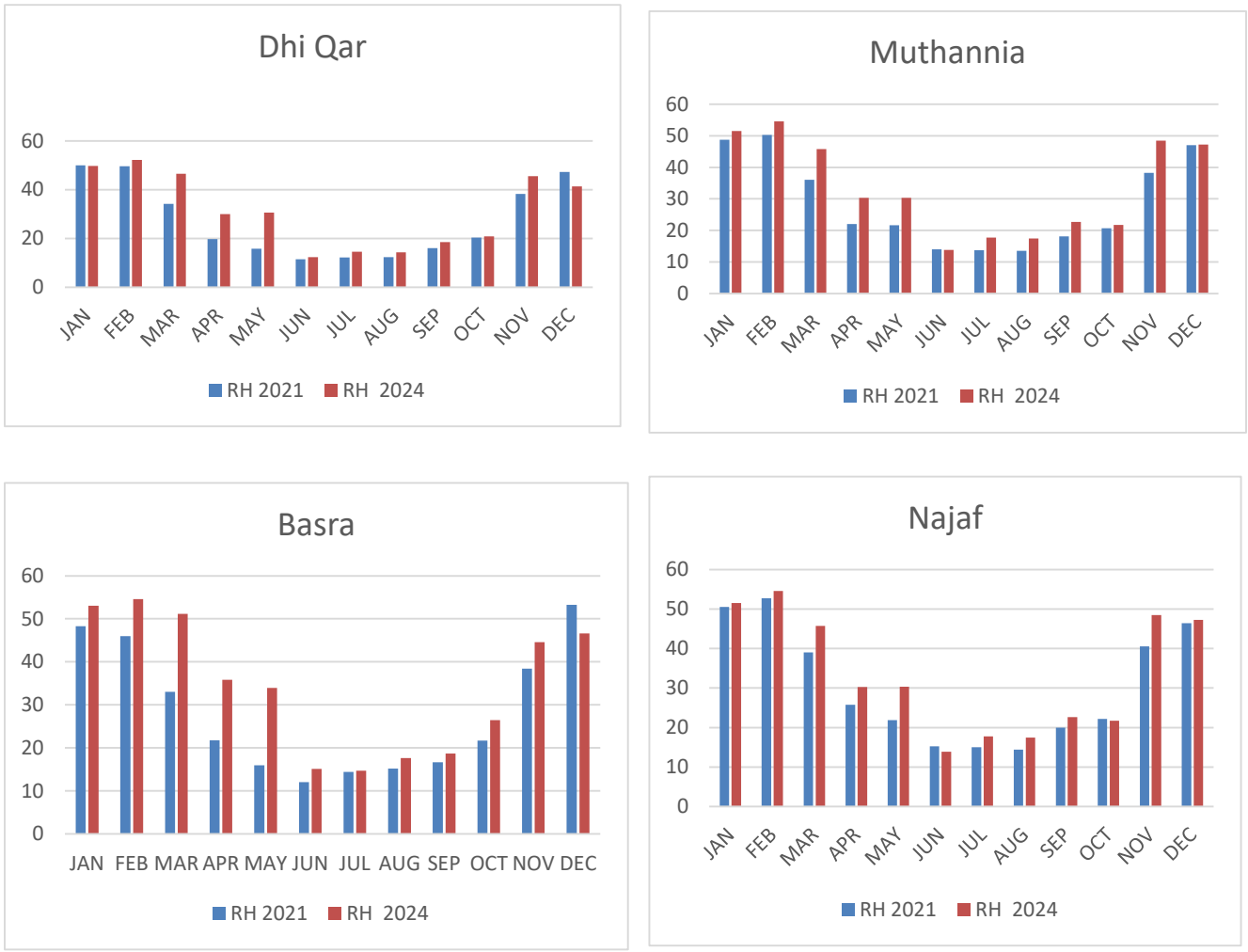


Fig 2: The following table shows the weather data for middle and south Iraq for relative humidity for the years 2021, and 2024.

Air pollution measurement

Fig 3 shows differences in air pollution levels in central and southern Iraq between 2021 and 2024. In 2021, Baghdad reported the highest nitrogen dioxide level at 161.45µmol/m²; in 2024, NO_2 levels were 158.55 umol/m². Human activity could alter air pollutants in Baghdad; hence, economic activity and population density could have an impact on the local distribution of air quality [25].

NO_2 levels in Qadisiyah Governorate hit 80.238 µmol/m² in 2021 and 70.063 µmol/m² in 2024. In the Babylon Governorate 2021 the levels of NO_2 hit 61.54µmol/m², and in 2024 it hit 60.066 µmol/m². The NO_2 level in Karbala Governorate in 2021 was 60.84µmol/m²; in 2024 it was 61.148µmol/m².

The level of NO_2 in Karbala Governorate in 2021 it reached 60.84µmol/m² and in 2024 it was 61.148µmol/m². The concentrations NO_2 in Najaf Governorate for the year 2021 it was (71.237 µmol/m²) and for the year 2024 it was (72.076 µmol/m²). Wasit in the year 2021 it reached (31.098µmol/m²) and in the year 2024 the concentrations reached (33.623 µmol/m²). In Maysan Governorate, the concentrations of NO_2 in 2021 it reached (44.99µmol/m²) and in 2024 it reached 42.756 micromol/m². As for Muthannia Governorate, the concentrations of NO_2 in 2021 it reached (39.101µmol/m²) and in 2024 it was (40.52 µmol/m²). The concentrations of NO_2 in Basra Governorate in 2024, (64.64µmol/m²). While in Dhi Qar

Governorate the concentrations of NO_2 in 2021 it reached (46.604µmol/m²), and in 2024 it was (45.85µmol/m²).

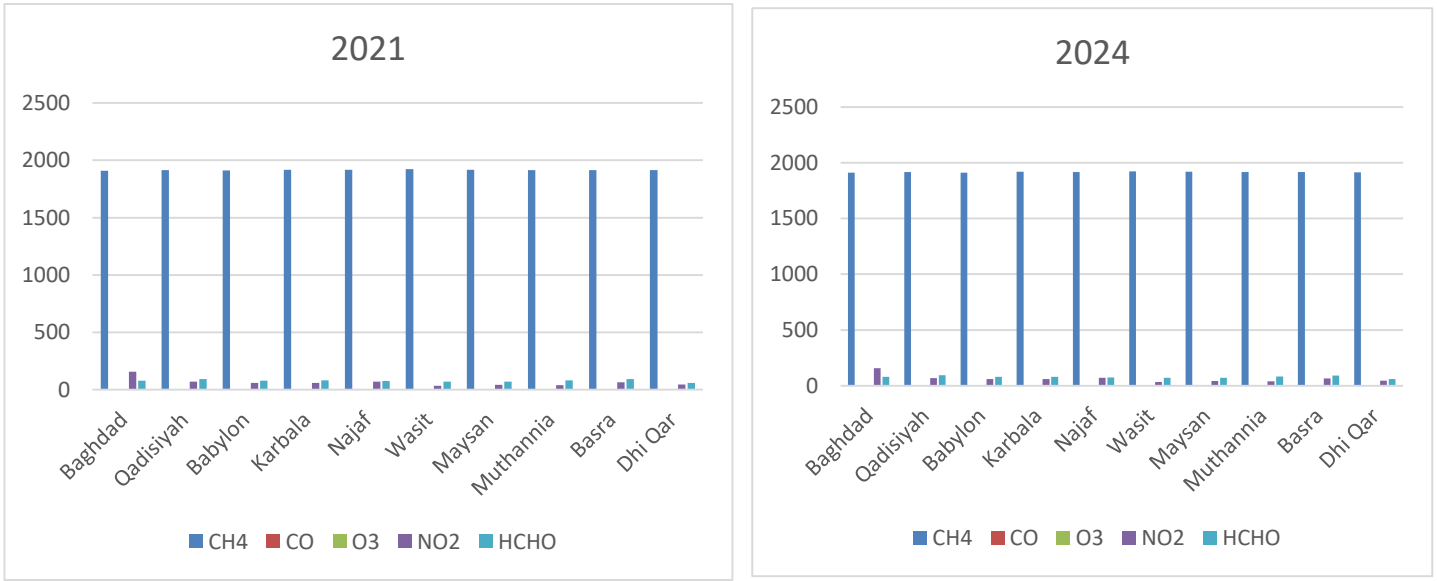
The highest concentration of CH_4 in Baghdad was recorded in 2021 (1887.471 ppmv), and in 2024, it reached (1910.028ppmv). In Qadisiyah Governorate, in 2021, and (1915.349ppmv) in 2024. In Babylon Governorate, the concentration of CH_4 reached (1893.121ppmv) in 2021, and in 2024 it reached (1911.057ppmv). The concentration of CH_4 in Karbala Governorate in 2021 it reached (1910.576 ppmv), In 2024 it was (1918.415 ppmv). The CH_4 concentration in Najaf Governorate in 2021 it was (1919.102ppmv) and in 2024, it was (1918.179 ppmv). Al-Wasit witnessed a CH_4 concentration in 2021, it reached (1907.09ppmv) , and in 2024 it reached (1923.342ppmv) . In Maysan Governorate, the concentration of CH_4 in in 2021 it reached (1907.078ppmv), and in 2024 it reached (1918.227ppmv). As for Muthannia Governorate, the concentration of methane gas in 2021 it reached (1910.134ppmv), and in 2024 it reached (1916.020 ppmv). In Basra Governorate, the concentration of CH_4 in 2021 it reached (1913.568 pppmv) , and in 2024, it reached (1916.05 ppmv). While in Dhi Qar Governorate, the concentration of CH_4 in 2021 it reached (1905.686 ppmv), and in 2024 it reached (1915.30 ppmv).Iraq is one of the countries in the Middle East most facing the impact of climatic changes, the most important of which are high average temperatures, decreasing amounts of precipitation, drought, and desertification. Methane (CH_4) is a greenhouse gas emitted by human activities and has a direct impact on the climate, absorbing part of the heat into the atmosphere and preventing its leakage into space, which leads to an increase in air temperature. This phenomenon is known as global warming [26]

The highest O_3 concentration was recorded in Baghdad in in 2021 (0.1292 mol/m²) and in 2024, it reached (0.1352 mol/m²). In Qadisiyah Governorate, the O_3 concentration reached (0.1277 mol/m²) in 2021, and (0.1322 mol/m²) in 2024. In Babylon Governorate, the O_3 concentration reached (0.1281 mol/m²) in 2021, and in 2024 it reached (0.1339 mol/m²). The O_3 concentration in Karbala Governorate in 2021 it reached (0.1283 mol/m²), and in 2024 it reached (0.1343 mol/m²). As for the O_3 concentration in Najaf Governorate reached in 2021 (0.1284 mol/m²), and in 2024 it reached (0.1338 mol/m²). Al-Wasit witnessed an O_3 concentration of 2021 it reached (0.1287 mol/m²), and in 2024 it reached (0.1331 mol/m²). In Amara Governorate, the O3 concentration in 2021 it reached (0.1274 mol/m²), and in 2024 it reached (0.1324 mol/m²). In Basra Governorate, the O_3 concentration in 2021 it reached (0.1267 mol/m²), and in 2024 it reached (0.1308 mol/m²). In Dhi Qar Governorate, the O_3 concentration reached (0.1270 mol/m²) in 2021, and (0.1307 mol/m²) in 2024. The decrease in O_3 levels in various regions of Iraq may be attributed to diminished solar insolation during the progressing months of winter [27]

The highest CO concentration was recorded in Baghdad in in 2021 (0.0341 mol/m²), and in 2024, it reached (0.0345 mol/m²). In Qadisiyah Governorate, the ozone concentration reached (0.0333 mol/m²) in 2021, and (0.0339 mol/m²) in 2024. In Babylon Governorate, the CO concentration reached (0.03315 mol/m²) in 2021, and in 2024 it reached (0.0339 mol/m²). The concentration of CO in Karbala Governorate in 2021 it reached (0.0325 mol/m²), and in 2024 it reached (0.0331 mol/m²). As for the concentration of CO in Najaf Governorate in 2021 it reached (0.0326 mol/m²), and in 2024 it reached (0.0329 mol/m²). Al-Wasit witnessed a concentration of CO in 2021 it reached (0.0322 mol/m²), and in 2024 it reached (0.0332 mol/m²). In Maysan Governorate, the concentration of CO in 2021 it reached (0.0325 mol/m²), and in 2024 it reached (0.0327 mol/m²). As for Muthannia Governorate, the concentration of CO in 2021 it reached (0.0328 mol/m²), and in 2024 it reached (0.0335 mol/m²). In Basra Governorate, the concentration of CO in in 2021 it reached (0.0320 mol/m²), and in 2024 it reached (0.0331 mol/m²). In Dhi Qar Governorate, the concentration of CO in 2021 it reached (0.0325 mol/m²) , and in 2024 it reached (0.03325 mol/m²).

The highest HCHO concentration was recorded in Baghdad in 2021 (67.918) and in 2024, it reached (78.847). In Qadisiyah Governorate, the HCHO concentration reached in 2021, and (94.09) in 2024. In Babylon Governorate, the HCHO concentration reached in 2021, and in 2024 it reached (80.38). The HCHO concentration in Karbala Governorate in 2021 it reached (71.17) , and in 2024 it reached (81.62) . As for the HCHO concentration in Najaf Governorate in 2021 it reached (74.29), and in 2024 it reached (75.29) . Al-Wasit witnessed an ozone concentration of 2021 it reached (57.61), and in 2024 it reached (71.93). In Maysan Governorate, the HCHO concentration in 2021 it reached (64.46), and in 2024 it reached (70.38). As for Muthannia Governorate, the HCHO concentration in 2021 it reached (65.86), and in 2024 it reached (82.26). In Basra Governorate, the HCHO concentration in 2021 it reached (84.80), and in 2024 it reached (92.77). In Dhi Qar Governorate, the HCHO concentration reached (60.76) in 2021, and (60.76) in 2024.

Fig 3. Annual mean concentrations of air pollution recorded from 2021 and 2024



Multivariate Analysis

Statistical methods include Pearson's correlation coefficients and principal component analysis (PCA) were used in this work. A statistical technique called the correlation coefficient measures how closely related two paired variables are [29]. Successfully controlling and preventing air pollution depends on knowing the factors affecting air quality [30]. Studies on the causes of urban industry-related air quality [31] as well as climate impact [32] have been conducted by researchers. The weather patterns were therefore used to determine how central and southern Iraq's air pollution affected. Thus, the levels of PM2.5 and O3 are greatly affected by meteorological conditions and contaminants[33].

The KMO statistic is 0.631 and principal components with eigenvalues over 1 should be retained (Kaiser criterion). The four components accounted for 87.342% of the whole variation (Table 4). The four components of the PCA were PC1, PC2, PC3 and PC4. Of the entire variation, PC1 was 29.469% (Table 5). While showing a negative correlation with CH4 and WS, PC1 showed significant variation with CO and NO2, suggesting that wind speed affects these gases in the central and southern Iraq environment. Furthermore, the research agreed with [34], which they found. Wind speed shows a notable negative correlation with AQI, PM2.5, PM10, SO2, NO2, and CO during the warm season. Comprising 26.849% of the overall variation, PC2 shows positive loadings between CH4 and O3 and negative with temperature, suggesting that these variables could affect the concentration of atmospheric CH4 and O3. Representing

16.784% of the overall variation, PC3 shows positive loadings between HCHO and relative humidity suggesting that relative humidity affected HCHO level. Representing 14.239% of the overall variation, PC4 shows just wind direction.

TABLE 4. total variance explained of PCA for meteorological parameters and air quality.

Total Variance Explained

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.437	38.186	38.186	2.652	29.469	29.469
2	2.322	25.805	63.992	2.416	26.849	56.319
3	1.072	11.910	75.902	1.511	16.784	73.103
4	1.030	11.440	87.342	1.282	14.239	87.342
5	0.431	4.788	92.130			
6	0.291	3.229	95.359			
7	0.216	2.400	97.759			
8	0.106	1.181	98.940			
9	0.095	1.060	100.000			

Extraction Method: Principal Component Analysis.

TABLE 5. Principal component analysis showed meteorological parameters influencing air quality (PCA loadings > 0.6)

Rotated Component Matrix[a]

	Component			
	1	2	3	4
CH4	-0.624	0.667	0.143	-0.263
O3	0.210	0.879	0.190	-0.004
CO	0.740	0.426	0.315	0.190
NO2	0.920	0.031	0.076	-0.080
HCHO	-0.003	0.505	0.672	-0.376
RH	0.022	0.045	0.929	0.154
WD	0.112	0.079	0.054	0.947
WS	-0.846	-0.279	0.178	-0.203
Temp	-0.308	-0.823	-0.017	-0.258

The Pearson correlation coefficient matrix (r) shown in Table 6 reveals the relationships between meteorological variables and air quality indicators. Reducing and controlling regional air pollution depends on a study of the distribution of air pollution and its causes in central and southern Iraq. The findings imply that temperature wind speed had a significant adverse relationship with CO. Ozone (O3) shows a significant negative relationship with temperature and none with wind speed; the findings contradicted a Chinese environmental governance study by [35]. Indicating that the rise in ozone concentration in the atmosphere is influenced by temperature. At most sites, relative humidity has been acknowledged as the main driver of

changes in CO level. Moreover, the sites where wind speed significantly affects CO concentration were mostly in central and southern Iraq, especially where Baghdad and Basra's gas use has risen because of oil refineries and other industrial activities inside the city. Wind speed has affected the air quality in the middle and south of Iraq; as we know, a rise in wind speed is good to enhancing air quality [36]. As the country undergoes climate change, causing higher atmospheric temperatures and more gas emissions, temperature has been acknowledged as a key meteorological factor affecting changes in CO and O3 levels over most parts of Iraq. The strong positive correlation between carbon monoxide (CO) and ozone (O3) matched the results of [1] in the oil fields of Basra city. Elevated air pollutants and aerosol particles along with increased O3 generation from various anthropogenic sources in middle and south Iraq cause this.

TABLE 6. Pearson correlation coefficient matrix between air quality values and meteorological parameters in middle and south of Iraq

Correlations

		CH4	O3	CO	NO2	HCHO	RH	WD	WS	Temp
CH4	Pearson Correlation	1	.463*	-.198	-.469*	.496*	.132	-.247	.398	-.268
O3	Pearson Correlation	.463*	1	.625**	.247	.525*	.204	.115	-.334	-.676**
CO	Pearson Correlation	-.198	.625**	1	.646**	.340	.313	.308	-.677**	-.566**
NO2	Pearson Correlation	-.469*	.247	.646**	1	.112	.048	.105	-.693**	-.265
HCHO	Pearson Correlation	.496*	.525*	.340	.112	1	.485*	-.203	.091	-.330
RH	Pearson Correlation	.132	.204	.313	.048	.485*	1	.123	.021	-.158
WD	Pearson Correlation	-.247	.115	.308	.105	-.203	.123	1	-.243	-.287
WS	Pearson Correlation	.398	-.334	-.677**	-.693**	.091	.021	-.243	1	.583**
Temp	Pearson Correlation	-.268	-.676**	-.566**	-.265	-.330	-.158	-.287	.583**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

CONCLUSION

This paper looked at certain gases released in central and southern Iraq over the last two years, including 2021 and 2024. The findings revealed differences in the levels of certain gases, most of which were in the cities of Baghdad and Basra for methane and nitrogen oxides, which must be regulated, particularly given most of the population suffers from these gaseous odors in the air, which could lead to different respiratory diseases in the long run. The PCA study indicated that climate variables affected yearly air pollution levels throughout years highlighted by a continuous increase in gases in Iraq ascribed to human activities.

REFERENCES

1. Kadhum, S. A., Hussain, L. I., Azeez, O. S., Abed, S. A., & Jaafar, B. I. (2025). The burden of air quality in neighborhoods near oil fields: an alarm for public health in Basra city, Iraq. *Bulletin of Atmospheric Science and Technology*, 6(1). https://doi.org/10.1007/s42865-024-00084-9
2. Bălă, G., Râjnoveanu, R., Tudorache, E., Motişan, R., & Oancea, C. (2021). Air pollution exposure—the (in)visible risk factor for respiratory diseases. Environmental Science and Pollution Research, 28(16), 19615–19628. https://doi.org/10.1007/s11356-021-13208-x
3. Ail Yaseen and A. K. J. A.-M. J. o. S. Abdulkareem, "Treatment Missing Data of Daily and Monthly Air Temperature in Some Iraqi cities by Using Curve Fitting," vol. 33, no. 4, pp. 34-41, 2022.

4. Borroni, E., Pesatori, A. C., Bollati, V., Buoli, M., & Carugno, M. (2021). Air pollution exposure and depression: A comprehensive updated systematic review and meta-analysis. *Environmental Pollution*, *292*, 118245. https://doi.org/10.1016/j.envpol.2021.118245
5. Ramasamy Jayamurugan, B. Kumaravel, S. Palanivelraja, and M. P. Chockalingam, "Influence of Temperature, Relative Humidity and Seasonal Variability on Ambient Air Quality in a Coastal Urban Area," International Journal of Atmospheric Sciences, vol. 2013, p. 264046, 2013/12/24 2013.
6. Chaichan, M.T., Kazem, H.A. & Abed, T.A. Traffic and outdoor air pollution levels near highways in Baghdad, Iraq. Environ Dev Sustain 20, 589–603 (2018). https://doi.org/10.1007/s10668-016-9900-x
7. Al-Hasnawi, S., Hussain, H. M., Al-Ansari, N., & Knutsson, S. (2016). The Effect of the Industrial Activities on Air Pollution at Baiji and its surrounding areas, Iraq. DIVA. https://ltu.diva-portal.org/smash/record.jsf?pid=diva2%3A984443&dswid=7919
8. Abbas, T. R., & Abbas, R. R. (2021). Assessing health impact of air pollutants in five Iraqi cities using AirQ+ model. IOP Conference Series Materials Science and Engineering, 1094(1), 012006. https://doi.org/10.1088/1757-899x/1094/1/012006
9. Sannigrahi, S., P. Kumar, A. Molter, Q. Zhang, B. Basu, A. Sarkar Basu, and F. Pilla. 2021. "Examining the Status of Improved Air Quality in World Cities Due to COVID-19 Led Temporary Reduction in Anthropogenic Emissions." Environmental Research 196: 110927. doi:10.1016/j.envres.2021. 110927.
10. Sharifi, A., & Felegari, S. (2022). Nitrogen dioxide (NO2) pollution monitoring with sentinel-5P satellite imagery over during the coronavirus pandemic (case study: Tehran). *Remote Sensing Letters*, *13*(10), 1029–1039. https://doi.org/10.1080/2150704x.2022.2120780
11. Dibs, H., Hasab, H.A., Al-Rifaie, J.K. et al. An Optimal Approach for Land-Use / Land-Cover Mapping by Integration and Fusion of Multispectral Landsat OLI Images: Case Study in Baghdad, Iraq. Water Air Soil Pollut 231, 488 (2020). https://doi.org/10.1007/s11270-020-04846-x
12. Muslih, K.D., Abbas, A.M. (2024). Climate of Iraq. In: Awadh, S.M., Al-Dabbas, M. (eds) The Geography of Iraq. World Regional Geography Book Series. Springer, Cham. https://doi.org/10.1007/978-3-031-71356-9_2
13. Jaafar, B. I., & Kadhum, S. A. (2023). Impact of particle size on heavy metal contamination in human health from sandstorms in Iraq. Journal of Trace Elements and Minerals, 6, 100108. https://doi.org/10.1016/j.jtemin.2023.100108
14. Sedgwick, P., 2012. Pearson's Correlation Coefficient. BMJ. https://doi.org/10.1136/ bmj.e4483 (Online) 345.
15. Ivanovski, M., Lavrič, P.D., Vončina, R., Gorič anec, D., Urbancl, D., 2022. Improvement of air quality during the COVID-19 lockdowns in the republic of Slovenia and its connection with meteorology. Aerosol Air. Qual. Res. 22 (9), 210262. https://doi. org/10.4209/aaqr.210262.
16. Konarska, J., Uddling, J., Holmer, B., Lutz, M., Lindberg, F., Pleijel, H., & Thorsson, S. (2014). Transpiration of urban trees and its cooling effect in a high latitude city. *International Journal of Biometeorology*, *50*(1), 1–10. https://doi.org/10.1007/s00484-014-0835-6
17. Lin, M., Chen, J., Zhang, Y., & Wang, Y. (2010). *Title of the article*. *Journal Name*, *Volume*(Issue), pages.https://doi.org/xxxxx Morakinyo, T. E., Dahanayake, K. K. C., Adegun, O. B., & Balogun, A. A. (2017). *Title of the article*. *Journal Name*, *Volume*(Issue), pages. https://doi.org/xxxxx
18. Abd Aliwie AN. A Pragmatic Analysis of Wish Strategies Used by Iraqi EFL Learners. Salud, Ciencia y Tecnología - Serie de Conferencias [Internet]. 2024 Aug. 12 [cited 2024 Sep. 6];3:.1151. Available from: https://conferencias.ageditor.ar/index.php/sctconf/article/view/1151
19. Aliwie, A.N.A., 2024. A Pragmatic Study of Irony in Dickens' 'A Tale of Two Cities'. Forum for Linguistic Studies. 6(6): 147–161. DOI: https://doi.org/10.30564/fls.v6i6.7056
20. Abd Aliwie, A.N., 2025. A Pragmatic Analysis of Persuasive Arguments in the 2011–2020 US Presidential Campaign Speeches. Forum for Linguistic Studies. 7(1): 480–494. DOI: https://doi.org/10.30564/fls.v7i1.7243
21. Abd Aliwie, A. N. (2025). Conversational Silence in Harold Pinter's The Birthday Party: A Pragmatic Perspective. International Journal of Arabic-English Studies. https://doi.org/10.33806/ijaes.v25i2.860

22. Ng, E., Chen, L., Wang, Y., & Yuan, C. (2012). A study on the cooling effects of greening in a high-density city: An experience from Hong Kong. *Building and Environment*, *47*, 256–271. https://doi.org/10.1016/j.buildenv.2011.07.014
23. Zölch, T., Maderspacher, J., Wamsler, C., & Pauleit, S. (2019). Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale. *Urban Forestry & Urban Greening*, *40*, 151–165. https://doi.org/10.1016/j.ufug.2019.03.006
24. Gao, Y., Xu, J., & Chen, D. (2014). The impacts of green areas on mitigating urban heat island effect: A review. *International Journal of Environmental Research and Public Health*, *11*(12), 123–145. https://doi.org/10.3390/ijerph11010123
25. Tran, H. T., Nguyen, T. M., & Le, Q. D. (2023). Evaluating the cooling effects of urban green spaces in tropical cities: A case study of Ho Chi Minh City, Vietnam. *Urban Climate*, *46*, 101–112. https://doi.org/10.1016/j.uclim.2023.101112
26. Zhu, J., and Yao, J. (2021). Socio - economic factors on air quality in 31 provincial capital cities in China. Environ. Sci. Surv. 40, 20–27. doi:10.13623/j.cnki.hkdk.2021.06.004
27. Yehia, M. A., Al-Taai, O. T., & Ibrahim, M. K. (2022). The chemical behaviour of greenhouse gases and its impact on climate change in Iraq. *Egyptian Journal of Chemistry*, *65*(12), 1373–1382. https://doi.org/10.21608/ejchem.2022.151633.6571
28. Liu, S., Zhao, W., Li, L., Jin, J., Li, T., Xu, H., Zhao, W. (2023). Meteorological mechanisms of regional PM2.5 and O3 transport in the North China Plain driven by the East Asian monsoon. Atmos. Pollut. Res. 14, 101638. https://doi.org/10.1016/j.apr.2022.101638
29. Kerr, J.B., McElroy, C.T., 1993. Evidence for large upward trends of ultraviolet-B radiation 634 linked to ozone depletion. Science. 262, 1032–1034. DOI 10.1126/science.262.5136.1032
30. Núñez-Alonso, D., Pérez-Arribas, L. V., Manzoor, S., & Cáceres, J. O. (2019). Statistical tools for air pollution assessment: Multivariate and spatial analysis studies in the Madrid region. *Journal of Analytical Methods in Chemistry*, *2019*, 1–9. https://doi.org/10.1155/2019/9753927
31. Yan, D., Zhou, M., Diao, Y., & Yang, M. (2022). Air pollution in China: Spatial patterns and spatial coupling with population and economy. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.1040131
32. Pei, Y., Zhu, Y., and Wang, N. (2021). Air pollution, industrial efficiency and industrial agglomeration. Ecol. Econ. 37, 176–184+222.
33. Liang, L., Chen, M., Luo, X., and Xian, Y. (2021). Changes pattern in the population and economic gravity centers since the Reform and Opening up inChina: The widening gaps between the South and North. J. Clean. Prod. 310, 127379. doi:10.1016/j.jclepro.2021.127379
34. Guan, R., Yu, J., Li, M., Yan, J., Liu, Z. (2021). Preparation of electrochemical sensor assisted unmanned aerial vehicles system for SO2, O3, NO2, CO and PM2.5/PM10 detection in air. Int. J. of Electrochem. Sci. 16, 211021. https://doi.org/10.20964/2021.10.28
35. Cui H., Ma R., Gao F., 2018, Relationship between Meteorological Factors and Diffusion of Atmospheric Pollutants, Chemical Engineering Transactions, 71, 1417-1422.
36. Liu, Y., Zhou, Y., & Lu, J. (2020b). Exploring the relationship between air pollution and meteorological conditions in China under environmental governance. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-71338-7
37. He, J. et al. Air pollution characteristics and their relation to meteorological conditions during 2014–2015 in major Chinese cities. Environ. Pollut. 223, 484–496 (2017).