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Original Research

Air Quality Assessment in Erbil, Iraq: Analysis of Major Pollutants and Meteorological Influences

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Abstract

Background: Air pollution remains a critical environmental and public health concern, particularly in rapidly urbanizing regions. In Iraq's Kurdistan Region, urban expansion and industrial activities have raised concerns regarding air quality in the capital, Erbil, especially during the winter months.

Aim: this study aimed to assess wintertime air quality in Erbil, evaluate the major air pollutants in relation to international and regional standards, and examine the influence of meteorological factors on pollutant behaviors and potential health risks.

Methods: This study was designed as an observational, retrospective time-series analysis to evaluate wintertime air quality in Erbil over three months from 1 December 2024 to 28 February 2025 using secondary data on six key air pollutants: PM2.5, PM10, NO_2, SO_2, CO, and O_3, obtained from The Weather Channel. The Air Quality Index (AQI) was applied to assess pollution levels and potential health risks. Statistical analyses (one-way ANOVA) with a significance level of $p \leq 0.05$ were conducted to examine temporal variations and inter-pollutant correlations, as well as the influence of meteorological factors on pollutant accumulation.

Results: Particulate matter concentrations (PM2.5 and PM10) frequently exceeded World Health Organization (WHO) recommended limits, particularly in December and January, indicating substantial air quality deterioration during colder months. In contrast, gaseous pollutants (CO, NO_2, SO_2, and O_3) generally remained within permissible levels. PM2.5 and PM10 showed a strong positive correlation ($r = 0.85$), suggesting common anthropogenic sources such as vehicular traffic and industrial emissions. Meteorological conditions, including temperature inversion and high humidity, were found to exacerbate particulate accumulation by reducing atmospheric dispersion.

Conclusion: The study highlights that wintertime air pollution in Erbil is primarily driven by particulate matter, intensified by meteorological and human factors. These findings offer essential insights for local environmental authorities to implement targeted air quality management strategies and mitigation policies, aiming to protect public health and promote sustainable urban development.

Keywords Air pollution, AQI, Erbil, Meteorological parameters, Urban environment

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Introduction

Air pollution is among our world's most pressing environmental challenges, widely acknowledged as a global concern (Manisalidis et al., 2020). It involves harmful elements, including gases, particulate matter, and biological agents, in our air that originate from both natural and anthropogenic sources. These contaminants can negatively impact both human health and the natural environment, (Ali et al., 2019; Mohammed et al., 2025; Qader, 2025). Air quality plays a vital role in public health and environmental sustainability, particularly in urban areas where industrial activities and vehicular emissions are prevalent. Poor air quality in urban areas may cause various health problems for people who are exposed to it in their everyday lives and is linked with increases in heart attacks, asthma, dementia, and cancer (Sarmiento et al., 2023; Qader et al., 2025). The main causes of poor air quality are vehicle exhaust and industrial sites located close to urban areas. The negative outcomes are mainly caused by the aerosol particles deposited in the respiratory tract during breathing and bloodstream, leading to chronic illness and premature mortality (Chen et al., 2024). According to the World Health Organization (WHO), 4.2 million people die yearly from outdoor air pollution, and 3.8 million people die from indoor air pollution. The premature mortality rate from air pollution is expected to double by 2050, which is emphasizing its growing threat to global health and environmental integrity (Pai et al., 2022). Erbil, the capital of the Kurdistan Region of Iraq, is experiencing rapid urbanization, leading to increased air pollution and associated health risks, alarmingly, the global burden of disease related to the air pollution is projected to increase substantially by 2050 if effective mitigation strategies are not implemented (Hama-Aziz, 2022; Qader, 2025; Shareef et al., 2025). Understanding the dynamics of air pollution and its health implications is essential for developing strategies to mitigate its impact on the city's residents. Furthermore, the region's air quality has not only been impacted by the oil and gas activities, but other sectors such as steel and chemical industries play a significant role in adding further air pollution into the atmosphere (Hilly et al., 2024). To better manage the air quality, the region has set a threshold limit for most air pollutants to be followed as a benchmark for the industries in terms of air pollutant emissions. This study uses data from the Weather Channel to focus on air quality and health risk assessment in Erbil during the winter months of December, January, and February. By analyzing key air pollutants such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3), along with meteorological parameters like temperature and humidity. Using data from The Weather Channel offers a practical and accessible approach to monitoring air pollution, ensuring a consistent and reliable source for environmental analysis. This study aims to analyze wintertime air quality in Erbil using secondary data from The Weather Channel for air major pollutants, compare the measured concentrations with WHO and Kurdistan Regional Government (KRG) air quality standards, also to evaluate pollutant correlations and temporal variations across the winter months, and identify potential meteorological influence on pollutant behavior. The findings of this research provide a scientific basis for local authorities to implement evidence-based air quality management strategies and contribute to the regional understanding of atmospheric pollution in the Middle Eastern urban environment.

Experimental methods

Study area

Erbil is the capital city of the Kurdistan Region of Iraq and represents one of the country's most rapidly expanding urban and industrial centers. Geographically, it is located between latitudes 35°30′ and 37°15′ N and longitudes 43°22′ and 45°05′ E, covering an area of approximately 14,818 km^2. The city's population is estimated at around 2.25 million inhabitants (Ali et al., 2023). Erbil experiences a semi-arid continental climate characterized by hot, dry summer and cold, relatively wet winters. During winter, stagnant air masses and temperature inversions often occur, leading to reduced pollutant dispersion and increased surface-level concentration of air contaminants. The city's air quality is influenced by diverse emission sources, including vehicular traffic, small-scale industries, power generation units, and domestic heating using fossil fuels.

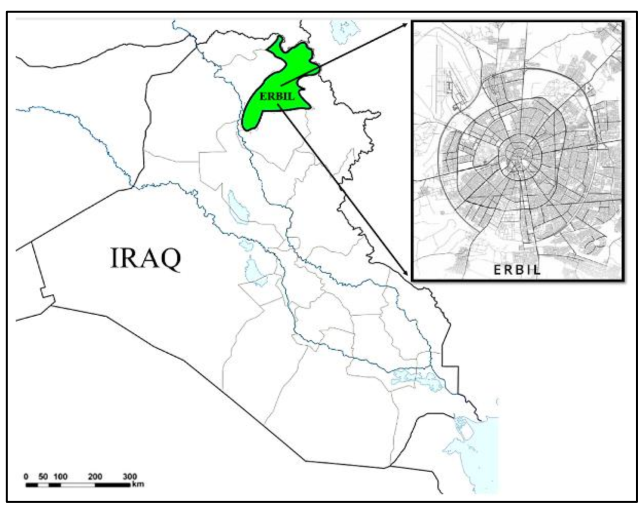

Figure 1: An Iraqi map displaying Erbil City's location.

Data source and parameters

The air pollution and meteorological data used in this study were obtained from The Weather Channel, which provides continuous, location-specific air quality information for Erbil. This platform was selected due to the limited availability of regulatory-grade monitoring stations in the region. The Weather Channel derives its pollutant estimates from a combination of ground-based sensors, satellite remote sensing, and atmospheric chemical transport models, which are integrated to generate hourly concentration values for major air pollutants. Such hybrid datasets have been widely used in regions with sparse monitoring coverage and are considered reliable for analyzing temporal trends. The pollutants examined in this study included sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), and carbon monoxide (CO), along with meteorological variables such as temperature and relative humidity.

Air Quality Index (AQI) calculation

Hourly pollutant concentrations were converted to 24-hour averages before AQI computation. For CO, NO_2, SO_2, and O_3, unit conversions from ppb or ppm to µg/m³ or mg/m³ were applied when necessary, following U.S. EPA conversion formulas. AQI values were calculated using the standard EPA equation, where pollutant concentrations (Cp) were first rounded to the nearest breakpoint range defined in Table 1. This approach ensures consistency with EPA guidance. Breakpoints for all pollutants, including ozone, have been updated and corrected in the revised table for AQI categories above 201. The purpose of the Air Quality Index (AQI) calculation was to evaluate air pollution severity and potential health implications. The U.S. Environmental Protection Agency (EPA) method (Fitz-Simons, 1999) was used, applying the following equation:

$$\mathbf{I}= \frac{(\mathrm{I\ Hi} - \mathrm{I\ Lo})}{(\mathrm{BP\ Hi} - \mathrm{BP\ Lo})} \times (\mathrm{Cp} - \mathrm{BP\ Lo}) + \mathrm{I\ Lo} \qquad (1)$$

Where:

I_p = Index value for pollutant p

C_p = Rounded concentration of pollutant $_p$

BP_{Hi} = Higher Breakpoint value of C_p

BP_{Lo} = Lower Breakpoint value of C_p

Hi = Index Breakpoint value of BP_{Hi}

I_{Lo} = Index Breakpoint value of BP_{Lo}

This formula was developed using data on air pollution concentrations, and Table 1 breakpoint table reveals that the index was split into six groups: Good (0–50), Normal (51–100), Hazardous (>300), Unhealthy for sensitive individuals (101–150), Unhealthy (151–200), and very unhealthy (201–300).

Table 1: U.S. EPA breakpoint concentrations for major air pollutants and their corresponding AQI categories

AQI	0–50	51–100	101–150	151–200	201–300	301–500
PM2.5 (µg/m³)	0–12	12.1–35.4	35.5–55.4	55.5–150.4	150.5–250.4	250.5–500.4
PM10 (µg/m³)	0–54	55–154	155–254	255–354	355–424	425–604
O_3 (ppm)	0-0.054	0.05–0.07	0.07–0.085	0.086–0.105	0.106–0.200	_
CO (ppm)	0–4.4	4.5–9.4	9.5–12.4	12.5–15.4	15.5–30.4	30.5–50.4
SO_2 (ppb)	0–35	36–75	76–185	186–304	305–604	605–1004
NO_2 (ppb)	0–53	54–100	101–360	361–649	650–1249	1250–2049

Data analysis

All statistical analyses were conducted using GraphPad Prism and Microsoft Excel. Descriptive statistics (mean ± standard error) were computed for each pollutant and meteorological variable. Analysis of variance (ANOVA) was performed to determine significant differences in pollutant concentrations across the three study months, with a significance level of $p \leq 0.05$ (Steel and Torrie, 1960). Correlation analysis was applied to explore relationships among pollutants and between pollutants and meteorological parameters. Results were graphically represented using bar charts and correlation matrices.

Comparison with air quality standards

To evaluate the pollution status of Erbil, observed pollutant concentrations were compared with the World Health Organization (Pai et al., 2022) and Kurdistan Regional Government (KRG) air quality standards. The comparison focused on 24-hour and annual permissible limits, as summarized in Tables 8 and 9 of the datasets. This comparison provided a reference for assessing exceedance levels and identifying pollutants posing potential health risks during the winter period.

Results and Discussion

Conditions of the weather throughout the research period

Meteorological parameters showed a strong influence on pollutant dispersion and accumulation in Erbil during the winter months. Mean monthly temperatures were 9.2 Cº, 8.5 Cº, and 7.5 Cº in December, January, and February, respectively. While relative humidity values averaged 59%, 59%, and 51%. These conditions reflect a typical winter pattern characterized by low thermal convection and stable atmospheric layers, favoring the accumulation of particulate and gaseous pollutants. Notably, the temporary closure of 40 factories in December by the Erbil Environmental Directorate resulted in a marked decline in pollutant concentrations later that month, demonstrating the sensitivity of air quality to emission control measures.

Table 2: Mean, standard error for air pollutants during (DEC-JAN-FEB) with temperature and humidity data represented as (mean ± SE)

Air pollutants (µg/m^3)	December	January	February
PM 2.5	31.97 ± 2.692	35.17 ± 2.196	26.14 ± 2.122
PM 10	34.59 ± 3.069	42.92 ± 2.872	30.54 ± 2.553
CO	847.5 ± 46.53	761.9 ± 32.32	615.4 ± 37.46
NO2	44.74 ± 2.407	41.77 ± 1.833	30.90 ± 2.180
SO2	23.70 ± 1.234	24.37 ± 1.157	16.80 ± 1.345
O3	49.08 ± 2.274	60.60 ±1.140	80.40 ±1.663
Temperature	9.2 Cº	8.5 Cº	7.5 Cº
Humidity	59%	59%	51%

Ozone (O3)

Ground-level ozone displayed an opposite seasonal pattern compared to other pollutants, with concentrations increasing from 49.08 ± 2.2.7 µg/m3 in December to 80.40 ± 1.66 µg/m3 in February. The rise in O_3 levels toward late winter is consistent with increased solar radiation and longer daylight duration, which enhance photochemical ozone formation. No significant exceedance of the WHO or KRG short-term ozone standards was observed, with similar results in (Cichowicz et al., 2017). Tukey analysis at P≤0.05 showed there are Significant variations between the months (Table 3) with a P-value (0.0001). The inverse correlation of O_3 with NO_2, CO, and PM fractions further supports its photochemical dependence on precursor availability and solar intensity (Seinfeld and Pandis, 2016). Reduced solar radiation limits photolysis of NO_2, suppressing ozone formation. This pattern is consistent with winter ozone studies conducted in Warsaw (Cichowicz et al., 2017) and northern China (Wang et al., 2010).

Table 3: Analysis of variance (ANOVA) results for ozone (O_3) concentrations among winter months

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	14656	2	7328	F (2, 87) = 78.62	P<0.0001
Residual (within columns)	8109	87	93.21		

Total	22765	89

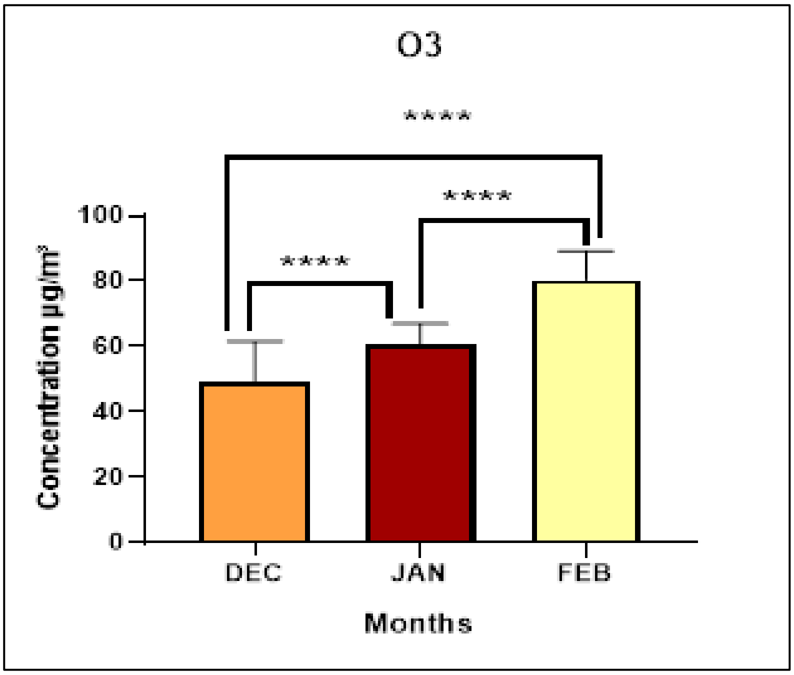

Figure 2: Comparison of O3 among months.

(CO)

CO concentrations exhibited a clear decreasing trend over the winter months, from 847.5 ± 46.5 µg/m3 in December to 615.4 ± 37.5 µg/m3 in February. The peak in December reflects intensified fuel combustion and heating activities, whereas lower values in February correspond to improved atmospheric dispersion and decreased energy demand. The high temperature on December 9.5 ºC (Table 2) also likely contributed to increased CO emissions, a similar result obtained by (Ravindiran et al., 2023). Although CO concentrations remained well below the WHO 24-hour guideline (4 mg/m3), significantly inter-month differences were observed ($p = 0.0004$). The high correlation between CO and NO2 supports the dominance of vehicular emissions as a major contributor to wintertime CO levels. Similar winter patterns have been documented in Baghdad, Tehran, and Ankara, confirming the role of human activity in shaping winter air quality in semi-arid urban regions.

Table 4: Analysis of variance (ANOVA) results for carbon monoxide (CO) concentrations among winter months

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	805300	2	402650	F (2, 87) = 8.657	P=0.0004
Residuals (within columns)	4046269	87	46509		
Total	4851569	89			

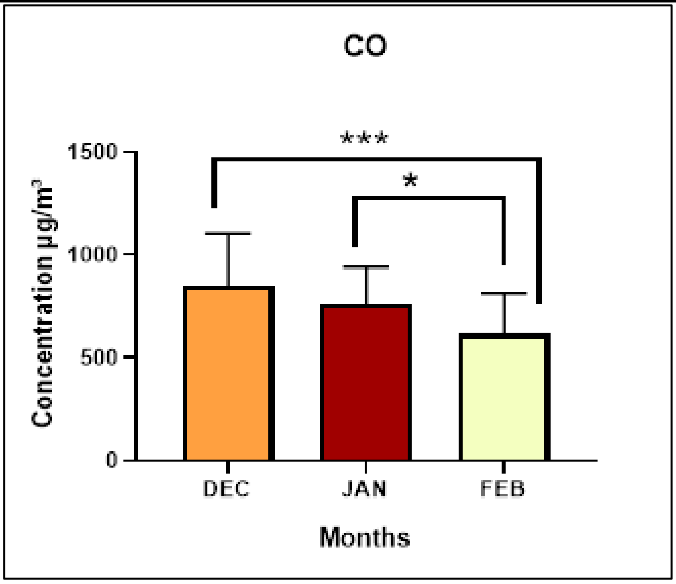

Figure 3: monthly variations of carbon monoxide (CO) concentrations during the winter season.

Particulate matter (PM 2.5 & PM 10)

Particulate matter indicated pronounced temporal variations during the study period (Table 2). Mean $PM_{2.5}$ concentrations ranged from 26.14 ± 2.12 µg/m³ in February to 35.17 ± 2.20 µg/m³ in January, while PM_{10} ranged between 30.54 ± 2.55 µg/m³ and 42.92 ± 2.87 µg/m³. Both pollutants peaked in January, coinciding with lower temperatures and steady atmospheric circumstances that restrict mixing vertically. These findings align with previous studies reporting wintertime PM accumulation due to temperature inversion and increased combustion activities (Cichowicz et al., 2017). When compared with air quality standards. PM2.5 concentrations exceeded both WHO (15 µg/m3, 24 h) and KRG (20 µg/m3, 24 h) limits, indicating potential health risks to sensitive populations. PM10 concentrations, though generally below KRG's 24-hour limit (60 µg/m3), occasionally approached or exceeded WHO's recommended thresholds (45 µg/m3). A comparable outcome was attained by Mohammed et al. (ANOVA analysis confirmed statistically significant monthly variations for both PM2.5 (P= 0.0304 and PM10 (P= 0.0102). The strong positive correlation between PM2.5 and PM10 (r = 0.85) suggests that both fractions come from common sources like vehicular emissions, industrial combustion, and re-suspended road dust. The observed decline in February corresponds to cooler temperatures and increased precipitation, which likely promoted wet deposition of particles. The inverse relationship between particulate matter and ozone observed in the correlation matrix (Figure 7) supports established photochemical mechanisms, where elevated PM concentrations reduce solar radiation and inhibit ozone formation (Seinfeld and Pandis, 2016).

These seasonal trends are consistent with findings from other semi-arid cities in the Middle East, including Amman, Tehran, and Sulaimaniyah, where winter inversions and increased combustion activities significantly elevate particulate concentrations. Temperature inversion events, which frequently occur during Erbil’s winter season, limit vertical mixing and trap pollutants near the ground. High humidity further enhances particle growth and reduces atmospheric dispersion. These meteorological conditions, combined with increased heating demand, explain the elevated PM levels observed in December and January.

Table 5: Analysis of variance (ANOVA) results for particulate matter ($PM_{2.5}$ and PM_{10}) concentrations among winter months

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
		PM2.5			
Treatment (between columns)	1224	2	611.8	F (2, 87) = 3.638	P=0.0304
Residual (within columns)	14633	87	168.2		

Total	15856	89			
		PM10			
Treatment (between columns)	2376	2	1188	F (2, 87) = 4.839	P=0.0102
Residual (within columns)	21359	87	245.5		
Total	23735	89			

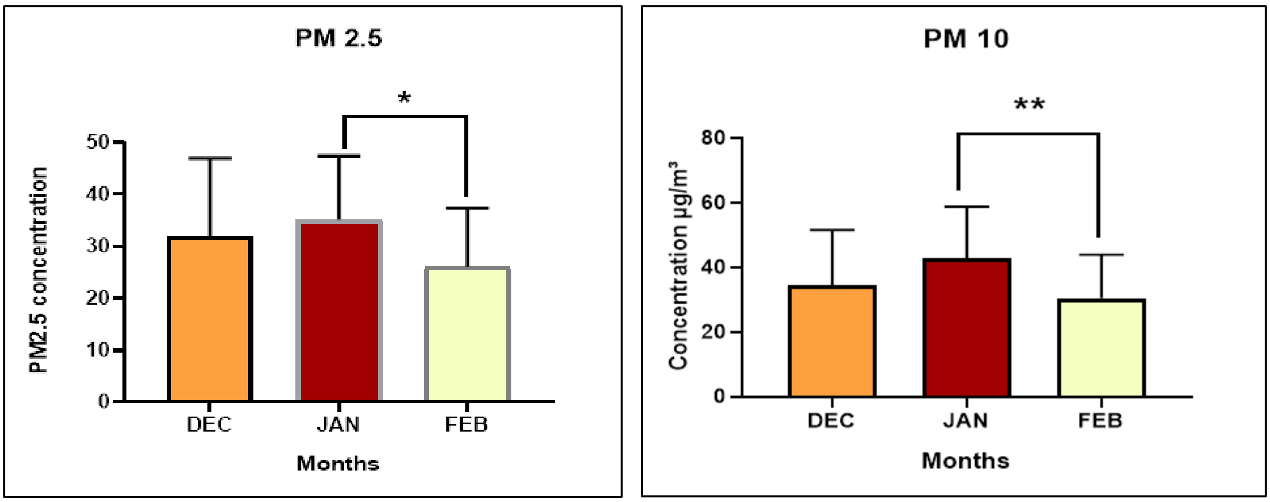

Figure 4: Monthly variation of particulate matter ($PM_{2.5}$ and PM_{10}) concentrations during the winter season.

(NO2)

NO2 levels were highest in December (44.74 µg/m³) and lowest in February (30.90 µg/m³). These fluctuations could be attributed to emissions from vehicles, power plants, illegal refinery is another cause, and meteorological conditions such as temperature and humidity also affect the NO2 levels. The study showed that the NO2 level increased with increasing temperature and humidity (Table 2). It could be due to an increase in traffic over the past three months due to the opening of schools, colleges, and government agencies. Compared with WHO and Kurdistan Regional Government (KRG) guidelines, NO2 levels exceeded the NO2 Recommended 24-hour limits according to WHO and lower levels according to KRG (25 µg/m³ for WHO and 80 µg/m³ for KRG), similar to (Mawlood and Sultan, 2022). Moreover, Tukey analysis ($p \leq 0.05$) confirmed significant monthly variations ($P = 0.0001$, (Table 6). NO_2 revealed a significant positive correlation (Figure 5) with CO ($r = 0.94$) and a negative correlation with O_3 (r = 0.55-), likely due to atmospheric chemistry, where higher NO_2 leads to NO production, reducing O_3 concentrations. Similarly, winter patterns have been documented in Baghdad, Tehran, and Ankara, confirming the role of human activity in shaping winter air quality in semi-arid urban regions.

Table 6: Analysis of variance (ANOVA) results for nitrogen dioxide (NO_2) concentrations among winter months

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	3080	2	1540	F (2, 87) = 11.07	P<0.0001
Residual (within columns)	12106	87	139.2		
Total	15186	89			

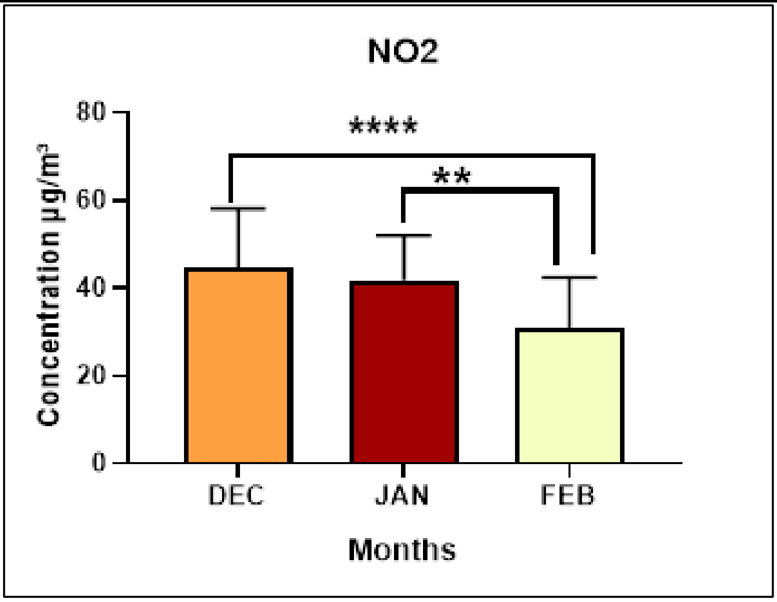

Figure 5: Monthly variation of nitrogen dioxide (NO2) concentrations during the winter season.

(SO2)

SO_2 concentrations ranged from 16.80 ± 1.35 µg/m3 in February to 24.37 ± 1.16 µg/m3 in January. Higher concentrations during December and January may be attributed to emissions from industrial activities, including a temporary illegal refinery operating in December. Despite these variations, SO_2 concentrations remained within WHO (40 µg/m3, 24 h) and KRG (80 µg/m3, 24 h) limits. ANOVA analysis revealed significant differences among months ($p < 0.0001$). Positive correlations with NO2 and CO further support the hypothesis of shared combustion sources, while the negative relationship with O3 highlights photochemical interactions that limit ozone generation. Comparable seasonal trends were reported in other studies with similar industrial emission profiles (Zoran et al., 2020; Wang et al., 2010). Similar winter patterns have been documented in Baghdad, Tehran, and Ankara, confirming the role of human activity in shaping winter air quality in semi-arid urban regions.

Table 7: analysis of variance (ANOVA) results for sulfur dioxide (SO2) concentrations among winter months

ANOVA table	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	1017	2	508.4	F (2, 87) = 10.98	P<0.0001
Residual (within columns)	4029	87	46.31		
Total	5046	89			

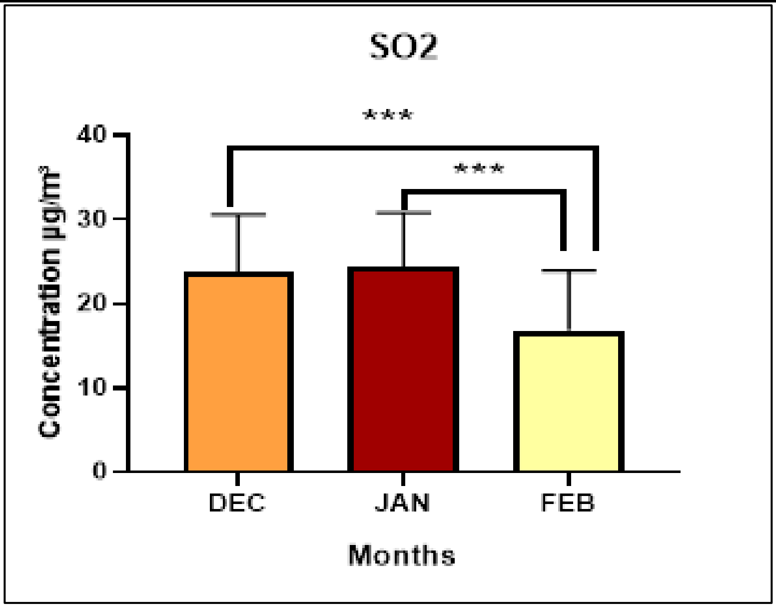

Figure 6: Monthly variation of sulfur dioxide (SO2) concentrations during the winter season.

Table 8: Kurdistan Regional Government (KRG) ambient air quality thresholds for major pollutants.

Pollutants	Average Time	Permissible Limits (µg/m³)
	1 hour	160
SO_2	24 hours	80
	Annual	60
	1 hour	120
NO_2	24 hours	80
	Annual	40
CO	1 hour	8
	8 hours	10
O_3	1 hour	120
	8 hours	100
PM2.5	24 hours	20
	Annual	10
PM10	24 hours	60
	Annual	40

Table 9: World Health Organization (WHO, 2021) air quality guideline values for major pollutants

Pollutant	Averaging Time	WHO Guideline Level
$PM_{2.5}$ (≤2.5 µm)	Annual	5 µg/m³
	24-hour	15 µg/m³
PM_{10} (≤10 µm)	Annual	15 µg/m³
	24-hour	45 µg/m³
O_3 (Ozone)	8-hour	100 µg/m³
NO_2 (Nitrogen Dioxide)	Annual	10 µg/m³
	24-hour	25 µg/m³
SO_2 (Sulfur Dioxide)	24-hour	40 µg/m³
CO (Carbon Monoxide)	24-hour	4 mg/m³

The correlation matrix (Fig. 7) demonstrated strong interrelationships among combustion-related pollutants (CO, NO2, and SO2), confirming their common anthropogenic origin. The negative correlation between ozone and these pollutants supports the expected photochemical balance between oxidant formation and precursor consumption. Confirming their common anthropogenic origin. The negative correlation between ozone and these pollutants supports the expected photochemical balance between oxidant formation and precursor consumption. These findings emphasize how air pollutants are interrelated, dynamic, and underscore the importance of integrated emission control strategies targeting traffic and industrial sources simultaneously.

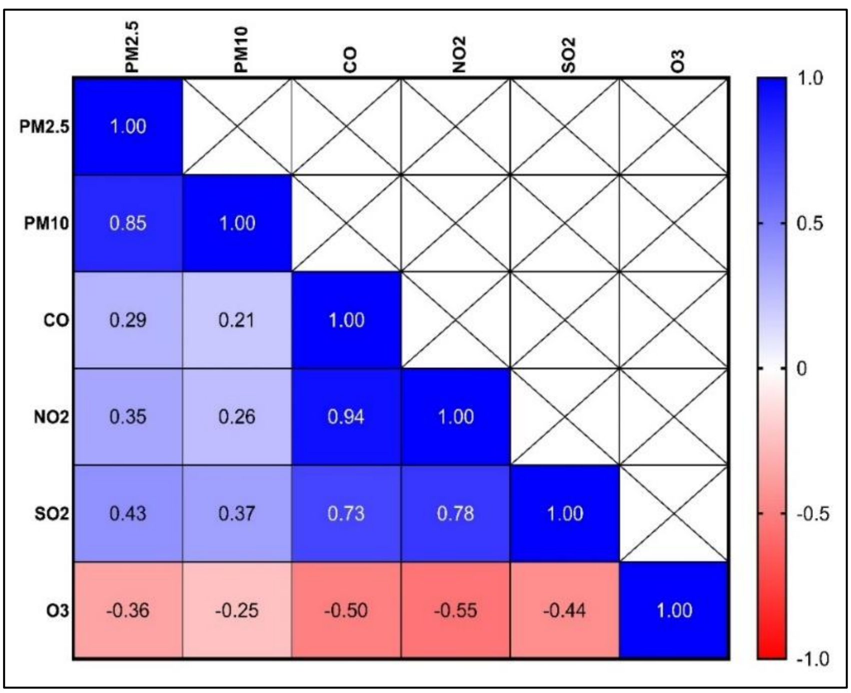

Figure 7: Correlation matrix illustrating interrelationships among the studied air pollutants.

Air quality index (AQI)

AQI values (Table 8-10) indicated that Erbil's winter air quality was primarily in the moderate to unhealthy range for vulnerable populations categories, driven mainly by elevated PM2.5 and PM10 concentrations. In December, PM10 contributed to an AQI value of 137.6, classified as unhealthy for sensitive groups, while PM2.5 remained moderate (83.4). January exhibited similar PM2.5 levels (AQI = 89.7), though PM10 values improved to the good range. In February, AQI levels for both particulate fractions fell within moderate or good categories, reflecting the influence of meteorological improvements and enforcement of emission controls. Other pollutants (NO2, SO2, CO, and O3) consistently remained within the good AQI category, indicating minimal direct health risk. The observed seasonal decline across all pollutants underscores the cumulative effect of rainfall, reduced energy use, and partial emission mitigation efforts.

Table 10: Values of the Air Quality Index (AQI) for major pollutants in December, January, and February

Pollutant	Concentration	AQI	Risk Result
		December	
PM2.5	31.96(µg/m3)	83.4	Moderate
PM10	34.59(µg/m3)	137.56	Unhealthy for sensitive people
NO2	23.77(ppb)	22.42	Good
SO2	9.00(ppb)	12.86	Good
O3	0.049(ppm)	41.59	Good
CO	0.73(ppm)	8.4	Good
		January	
PM2.5	35.166(µg/m3)	89.7	moderate
PM10	42.916(µg/m3)	39.737	Good
NO2	13.871(ppb)	13.086	Good
SO2	8.530(ppb)	12.185	Good
O3	0.0314(ppm)	26.689	Good
CO	0.711(ppm)	8.087	Good
		February	
PM2.5	26.13(µg/m3)	71.93	Moderate
PM10	30.53(µg/m3)	28.27	Good
NO2	7.31(ppb)	6.9	Good
SO2	5.20(ppb)	7.44	Good
O3	0.04(ppm)	35.21	Good
CO	0.02(ppm)	0.009	Good

Study Limitations

This study relied on air quality estimates generated by The

Weather Channel, which integrates ground sensors, satellite retrievals, and atmospheric modeling. Although this approach provides continuous coverage for regions lacking regulatory monitoring stations, it may introduce uncertainties when compared to high-precision reference monitors. In addition, spatial variation in pollutant levels across Erbil could not be assessed due to the use of a single data source. Despite these limitations, the dataset offers valuable insights into winter pollution trends and is suitable for temporal and comparative analysis.

Conclusion

This study offers a thorough examination of air quality in Erbil during the winter months, focusing on key pollutants such as PM2.5, PM10, NO2, SO2, CO, and O3. The findings reveal that Particulate matter (PM2.5 and PM10) often surpassed World Health Organization (WHO) standards. Guidelines pose significant health risks, particularly for vulnerable populations. Other pollutants, including NO2 and CO, exhibited seasonal fluctuations influenced by traffic density and industrial activities but generally remained within permissible limits. The results underscore the function of climatic elements like humidity and temperature inversions in exacerbating pollution levels during winter. The temporary closure of factories and the enforcement of environmental regulations demonstrated a measurable reduction in pollutant concentrations, highlighting the effectiveness of targeted interventions.

Statements and Declarations

Funding None.

Competing Interests The authors declare no conflict of interest.

Ethics Statement This study was reviewed and approved by the Medical Ethics Committee of Salahaddin University, Erbil, Iraq, during their eighth meeting (Paper Code: 9B) held on 1 September 2025. All study procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki, and written informed consent was obtained from all participants prior to their inclusion in the study.

Data Availability Statement The data that support the findings of this study are available from the corresponding author upon reasonable request.

Clinical trial registration This study did not constitute a clinical trial and therefore did not require registration.

Transparency Statement The lead author Shahla Sherwan Rassol affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Permission to reproduce material from other sources There are no reproduced materials in the current study.

Author Contributions Amina Mudhafur Mahmood & Jihan Omer Abdullah: Writing original draft, Analysis interpretation of data and Visualization, Conceptualization and Editing & final approval of the version submitted. Shahla Sherwan Rassol: Editing, writing and analysis.

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