



Original Research / Orijinal Araştırma

Relationship Between Air Pollution and Symptom-Diagnosis-Based Visits in Primary Care

Birinci Basamakta Hava Kirliliği ile Semptom ve Tanı Temelli Başvurular Arasındaki İlişki

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Abstract

Introduction: Air pollution is associated with adverse health outcomes, but most evidence comes from hospital data. Primary care records may capture earlier and milder presentations. This study aimed to evaluate the association between monthly changes in air pollutants and primary health care visits, stratified by symptoms and diagnosis, particularly respiratory infections and non-specific complaints such as headache and fatigue.

Materials and Methods: This retrospective observational study analyzed monthly visit counts from four family health centers located closest to an official air-quality monitoring station in Karatay, Konya, Türkiye, between April 2024 and April 2025. Outcomes were defined using ICD-10 codes for upper respiratory tract infections (URTI), lower respiratory tract infections (LRTI), headache, and malaise/fatigue. Monthly mean concentrations of PM_{2.5}, PM₁₀, O₃, NO₂, SO₂, and CO were obtained from public monitoring data.

Results: Respiratory visits increased during December 2024–January 2025, when pollutant levels peaked. Same-month analyses showed the strongest respiratory associations with SO₂ (URTI: p=0.005; LRTI: p<0.001) and CO (URTI: p=0.027, LRTI: p<0.001), while particulate matter was more consistently linked to LRTI (PM_{2.5}: p=0.018, PM₁₀: p=0.036). Headache visits were inversely associated with O₃ (p=0.039).

Conclusion: Poorer air quality—particularly elevated SO₂ and CO—was associated with increased respiratory visits in primary care, while headache presentations showed an ozone-related pattern. Primary care data may support local service planning during pollution peaks.

Keywords: Air Pollution; Environmental Health; Respiratory Tract Infections

Özet

Giriş: Hava kirliliği kötü sağlık sonuçlarıyla ilişkilidir; ancak mevcut kanıtların çoğu hastane verilerine dayanmaktadır. Birinci basamak kayıtları daha erken ve daha hafif klinik başvuruları yakalayabilir. Bu çalışmanın amacı, hava kirlenmelerindeki aylık değişimler ile birinci basamaktaki semptom ve tanı bazlı başvurular arasındaki ilişkiyi, özellikle solunum yolu enfeksiyonları, baş ağrısı ve halsizlik/yorgunluk gibi şikayetlere odaklanarak değerlendirmektir.

Yöntem: Bu retrospektif gözlemsel çalışmada, Nisan 2024 ile Nisan 2025 tarihleri arasında Karatay, Konya, Türkiye'deki resmi bir hava kalitesi izleme istasyonuna en yakın konumda bulunan dört aile sağlığı merkezinden alınan aylık ziyaret sayıları analiz edildi. Üst solunum yolu enfeksiyonları (ÜSYE), alt solunum yolu enfeksiyonları (ASYE), baş ağrısı ve halsizlik/yorgunluk için ICD-10 kodlarına göre tanımlandı. PM_{2.5}, PM₁₀, O₃, NO₂, SO₂ ve CO'ya ait aylık ortalama konsantrasyonlar kamuya açık izlem verilerinden elde edildi.

Bulgular: Solunum yolu başvuruları, kirlenici düzeylerinin zirve yaptığı Aralık 2024–Ocak 2025 döneminde arttı. Aynı ay analizlerinde en güçlü solunum yolu ilişkileri SO₂ (ÜSYE: p=0.005; ASYE: p<0.001) ve CO (ÜSYE: p=0.027, ASYE: p<0.001) ile saptanırken, partikül madde alt solunum yolu enfeksiyonları ile daha tutarlı ilişki gösterdi (PM_{2.5}: p=0.018, PM₁₀: p=0.036). Baş ağrısı başvuruları O₃ ile ters yönlü ilişkili bulundu (p=0.039).

Sonuç: Kötü hava kalitesi birinci basamakta solunum yolu enfeksiyonu başvurularındaki artışla ilişkili bulundu; baş ağrısı başvuruları ise ozonla ilişkili özgün bir örüntü gösterdi. Birinci basamak verileri, hava kirliliği artış dönemlerinde yerel sağlık hizmeti planlamasını destekleyebilir.

Anahtar Kelimeler: Çevre sağlığı, Hava kirliliği, Solunum yolu enfeksiyonları

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Introduction

Air pollution remains a major public health concern due to its complex composition and widespread harmful effects. It contributes to cardiovascular and respiratory morbidity and may also affect other organ systems. Major outdoor sources include fossil fuel and biomass combustion, traffic emissions, and industrial activities, while the resulting disease burden imposes substantial economic costs.^{1,2} The World Health Organization identifies air pollution as one of the most serious environmental risks to health. Short- and long-term exposure to particulate matter (PM_{2.5} and PM₁₀), ozone (O₃), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), and carbon monoxide (CO) has been associated with increased respiratory and cardiovascular disease.^{1,3} PM_{2.5} (aerodynamic diameter <2.5 µm) is particularly concerning because it can penetrate deep into the airways and aggravate existing conditions.^{1,4,5} A 10 µg/m³ reduction in PM_{2.5} has been linked to an estimated life-expectancy gain of 0.61±0.20 years.⁵ Recent research has also explored associations with neurological complaints, including headache disorders such as migraine.² In addition, an adolescent cohort study reported that higher NO₂ and CO levels were related to more frequent fatigue and emotional distress.⁶

Many studies have examined air pollution using hospital and emergency department data.^{4,7-12} In contrast, fewer investigations have focused on primary care visits. Evaluating pollutant levels alongside symptom-based presentations (e.g., headache, fatigue) and diagnosis-based encounters (e.g., respiratory tract infections) in primary care may provide actionable evidence for early public health warning strategies.¹³⁻¹⁵ As the first point of contact within the health system, primary care is well positioned to detect early and subtle shifts in population health related to environmental exposures.¹³ However, most primary care-based research has centered on respiratory outcomes, with broader systemic and non-respiratory effects receiving less attention.^{13,15,16}

In Türkiye, studies using routine first-contact healthcare records are still limited. Therefore, this study aimed to evaluate the association between monthly ambient air pollutant concentrations and primary care visit counts for both diagnosis-based outcomes and symptom-based presentations in a district of Konya, Türkiye. Understanding these associations at the primary care level is clinically relevant because it may support early detection of pollution-related health burden, inform local resource planning during high-pollution periods, and contribute to the development of community-level environmental health warning strategies. A key novelty of this study is that it examines symptom-based presentations (headache and malaise/fatigue) together with diagnosis-based respiratory infections in the same district — a combined approach that is rarely reported in prior studies.

Materials and Methods

This retrospective and observational study was conducted in Karatay, a district of Konya, Türkiye. We used routinely recorded data from four family health centers located closest to the official air quality monitoring station in Karatay. We reviewed primary care visits over 13 months, from April 2024 to April 2025. Associations between common air pollutants and both symptom- and diagnosis-based visit counts were explored, with additional analyses to assess whether effects appeared in the same month or with a short delay. Konya has a semi-arid steppe climate with hot, dry summers and relatively limited precipitation. In addition, the region's basin-like topography may promote fog and temperature inversions, which can prolong the residence time of pollutants in the lower atmosphere.¹⁷

Monthly visit counts were extracted from the electronic medical record systems of the participating family health centers. We examined both diagnosis- and symptom-based presentations, including upper respiratory tract infections (URTIs), lower respiratory tract infections (LRTIs), headache, and malaise/fatigue. Conditions were identified using ICD-10 codes: URTI (J00–J06), LRTI (J20–J22), headache (R51), and malaise/fatigue (R53). All analyses were performed using monthly visit counts for each outcome. Ambient air pollution data for the study period were obtained from publicly available measurements reported by an official monitoring station located in Karatay.¹⁸ The pollutants examined were PM_{2.5}, PM₁₀, O₃, NO₂, SO₂, and CO. For each pollutant, we computed monthly mean concentrations.

This study was based on aggregated monthly visit counts rather than individual patient records. All registered patients of the four participating family health centers who presented during the study period (April 2024–April 2025) and received one of the predefined ICD-10 codes were included in the monthly counts. No random sampling was applied; the study population comprised the complete set of coded visits at these centers during the observation period. Because analyses were conducted at the aggregate (monthly count) level rather than the individual patient level, it was not possible to apply individual-level inclusion or exclusion criteria such as the presence of chronic disease, pre-existing migraine or other chronic headache disorders, pregnancy, or sleep disorders. This constitutes an inherent limitation of the study design and is discussed further in the limitations section.

Due to the limited number of monthly observations and non-normal distributions, Spearman's rank correlation was used to assess monotonic associations between monthly pollutant levels and visit counts. Delayed effects were examined using one-month lagged (Lag 1) and two-month lagged (Lag 2) exposures, with Lag 0 representing the

same month. Because lagging reduces the number of observations, Lag 0 results within the lagged dataset may differ from full-series same-month correlations. For concise reporting, the “best lag” was defined as the lag (0–2 months) with the largest absolute Spearman’s rho for each pollutant–outcome pair, and its p-value was presented. Analyses were performed in Python 3.10 (pandas, SciPy, Matplotlib), with $p<0.05$ considered statistically significant.

Results

A marked increase in LRTI and URTI visits was observed in December 2024 and January 2025. This spike coincided with peak concentrations of PM_{2.5}, PM₁₀, NO₂, SO₂, and CO during the same period. Fatigue-related visits showed a gradual upward trend beginning in late summer, reaching their highest level in April 2025. The number of headache-related visits remained relatively low in the first half of the year but increased notably after January 2025. This increase corresponded with a decline in O₃ levels. Monthly symptoms and diagnosis-based visit counts, along with corresponding average pollutant concentrations, are illustrated in Figure 1.

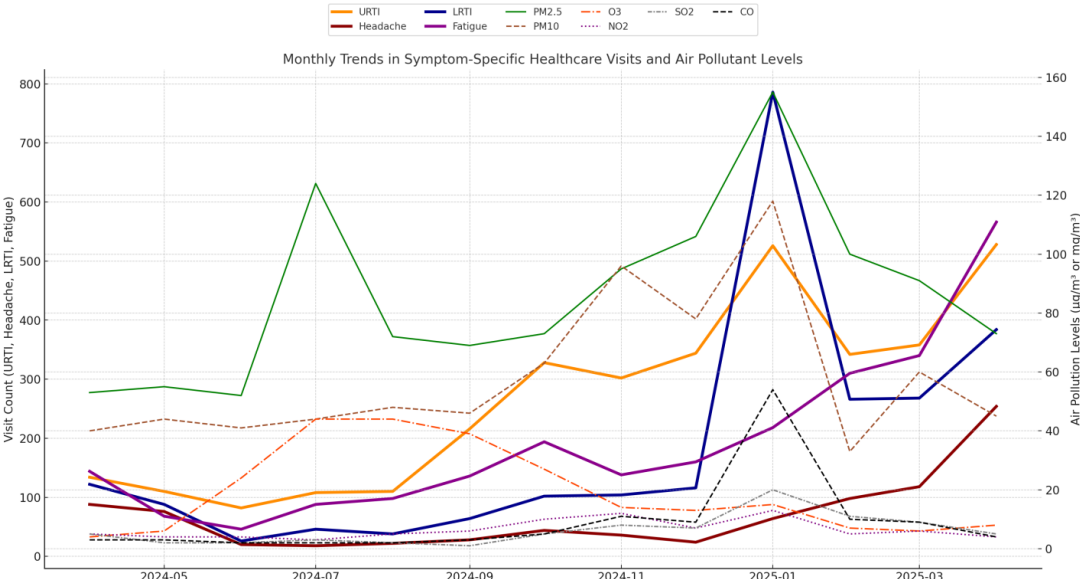


Figure 1. Monthly trends in symptoms- and diagnosis-specific healthcare visits alongside air pollutant levels. The left axis represents the monthly number of visits for four different symptoms, while the right axis shows the average concentration levels of the respective air pollutants.

URT: Upper Respiratory Tract Infections, LRT: Lower Respiratory Tract Infections, PM_{2.5}: Particulate Matter with a diameter of 2.5 micrometers or less, PM₁₀: Particulate Matter with a diameter of 10 micrometers or less. Across the 13-month series, same-month correlation analyses showed that LRTI visits were strongly and positively associated with CO and SO₂ (both $p<0.001$) and were also moderately correlated with PM_{2.5} ($p=0.018$) and PM₁₀ ($p=0.036$). URTI visits were strongly correlated with SO₂ ($p=0.005$) and showed moderate positive relationships with CO ($p=0.027$), while a borderline significant positive correlation was observed with PM₁₀ ($p=0.050$). Headache visits demonstrated a significant inverse correlation with O₃ ($p=0.039$). In these same-month analyses, malaise/fatigue did not show a statistically significant association with any pollutant. The full set of correlation coefficients is presented in Table 1 and visualized in Figure 2.

Table 1. Correlation Coefficients Between Air Pollutants and Symptom-Based Healthcare Visits

Parameter	URT	LRT	Headache	Malaise/Fatigue
PM _{2.5} (µg/m ³)	0.527 (p=0.064)	0.642 (p=0.018)	-0.116 (p=0.705)	0.134 (p=0.663)
PM ₁₀ (µg/m ³)	0.553 (p=0.050)	0.585 (p=0.036)	-0.182 (p=0.552)	-0.011 (p=0.970)
O ₃ (µg/m ³)	-0.432 (p=0.140)	-0.393 (p=0.184)	-0.576 (p=0.039)	-0.457 (p=0.117)
NO ₂ (µg/m ³)	0.535 (p=0.060)	0.494 (p=0.086)	-0.204 (p=0.504)	-0.008 (p=0.980)
SO ₂ (µg/m ³)	0.724 (p=0.005)	0.88 (p<0.001)	0.161 (p=0.599)	0.338 (p=0.258)
CO (mg/m ³)	0.609 (p=0.027)	0.889 (p<0.001)	0.003 (p=0.992)	0.130 (p=0.673)

Spearman’s correlation test was used. Spearman correlation coefficients with p-values in parentheses. URT: Upper Respiratory Tract Infections, LRT: Lower Respiratory Tract Infections, PM_{2.5}: Particulate Matter with a diameter of 2.5 micrometers or less, PM₁₀: Particulate Matter with a diameter of 10 micrometers or less.

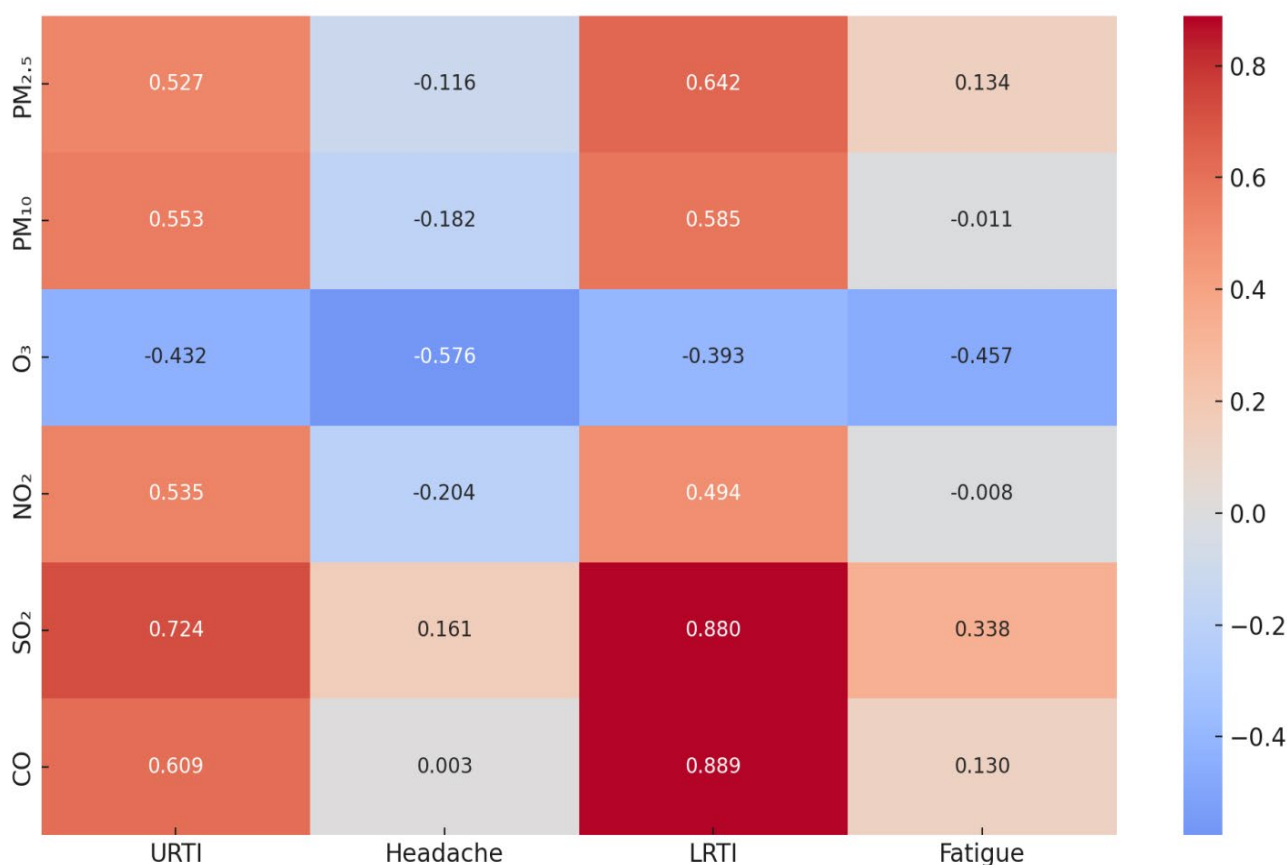


Figure 2. Heat map illustrates the correlations between air pollutant levels and diagnosis- and symptom-based primary care visits.

Spearman’s correlation test was used. Diagnoses and symptoms are presented on the horizontal axis, while air pollutants are listed on the vertical axis. Positive correlations are shown in shades of red, whereas negative correlations are represented in shades of blue. URTI: Upper Respiratory Tract Infections, LRTI: Lower Respiratory Tract Infections, PM_{2.5}: Particulate Matter with a diameter of 2.5 micrometers or less, PM₁₀: Particulate Matter with a diameter of 10 micrometers or less.

Lag analyses indicated pollutant-specific timing patterns. CO was most strongly associated with URTI in the same month (Lag 0, $p=0.001$) but with LRTI after two months (Lag 2, $p=0.002$); for malaise/fatigue, the strongest link appeared at Lag 1 ($p=0.010$). SO₂ showed predominantly immediate effects, with the strongest associations at Lag 0 for URTI ($p=0.005$), LRTI ($p=0.001$), and malaise/fatigue ($p=0.004$). In contrast, NO₂ and PM_{2.5} displayed delayed patterns, with their strongest associations generally at Lag 2 across outcomes. Headache visits were most closely related to O₃ in the same month (Lag 0, $p=0.001$) (Table 2).

Table 2. Strongest lagged associations between air pollutants and primary care visits

Outcome	Pollutant	Best Lag	Spearman’s ρ	p-value
URT	CO	Lag 0	0.791	0.001
URT	SO ₂	Lag 0	0.723	0.005
URT	NO ₂	Lag 2	0.667	0.025
URT	PM _{2.5}	Lag 2	0.664	0.026
LRT	CO	Lag 2	0.815	0.002
LRT	SO ₂	Lag 0	0.817	0.001
LRT	NO ₂	Lag 2	0.722	0.012
Headache	O ₃	Lag 0	-0.785	0.001
Headache	PM _{2.5}	Lag 2	0.745	0.008
Malaise/Fatigue	PM _{2.5}	Lag 2	0.736	0.010
Malaise/Fatigue	SO ₂	Lag 0	0.739	0.004
Malaise/Fatigue	CO	Lag 1	0.707	0.010

Spearman's correlation analysis with lagged variables was used. The dataset for the lag analyses contains fewer monthly observations than the full 13-month series used in Table 1 due to the inclusion of lagged variables (Lag 1 and Lag 2). Consequently, the same-month (Lag 0) coefficients and p-values in this restricted dataset slightly differ from those presented in the full-series analysis of Table 1.

URTI: Upper Respiratory Tract Infections, LRTI: Lower Respiratory Tract Infections, PM_{2.5}: Particulate Matter with a diameter of 2.5 micrometers or less, PM₁₀: Particulate Matter with a diameter of 10 micrometers or less, O₃: Ozone, NO₂: Nitrogen Dioxide, SO₂: Sulfur Dioxide, CO: Carbon Monoxide.

Discussion

During the winter months, particularly in December 2024 and January 2025, when a number of air contaminants peaked, we saw a distinct seasonal increase in respiratory tract infection visits. Local conditions in Konya are likely to contribute to this winter clustering. The city lies in a basin that can trap polluted air near the ground during temperature inversions. Its frequent winter fog further prolongs the presence of particulate matter in the lower atmosphere.¹⁷ Such conditions create stagnant, polluted air episodes in winter. The health burden of air pollution is well recognized globally,^{1,3} but much of the evidence comes from studies of hospital admissions and mortality rather than routine primary care data. Primary care sits at the broad base of the “pyramid” of pollution-related illness, yet it has been studied less often than hospital-based outcomes.^{13,15,16} Evidence is now emerging that the impact of pollution is detectable even in community healthcare settings. For example, a recent systematic review focusing on children found that short-term increases in air pollution were associated with more respiratory consultations in primary care.¹⁶ Our findings add to this growing literature by demonstrating similar patterns in a district-level primary care setting in Türkiye.

In our analysis, the clearest signals linking air quality to respiratory illnesses were tied to combustion-related pollutants from heating and traffic. Higher monthly levels of SO₂ and CO showed strong positive associations with respiratory infection visit counts, especially for LRTI; CO was also significantly associated with URTI in the same month. This pattern is consistent with a common winter scenario: as emissions from domestic heating and vehicle traffic increase, community respiratory complaints rise in parallel. Similar patterns have been reported elsewhere. In İzmir, higher SO₂, CO, and particulate levels coincided with increases in emergency department visits for respiratory and cardiovascular problems.⁷ Primary care studies also show comparable signals: outpatient URTI consultations rose with PM₁₀, NO₂, O₃, and SO₂ in Hong Kong,¹⁹ and GP consultations for upper respiratory complaints increased with PM₁₀ and SO₂ in London.¹⁴ A time-series study from the UK similarly found that every 10 µg/m³ increase in NO₂ and PM_{2.5} above WHO thresholds was associated with immediate relative risks of 1.09 and 1.06, respectively, for GP respiratory visits, with lagged effects persisting up to 100 days post-exposure.²⁰ Evidence from Türkiye is consistent as well; in coal-dependent Zonguldak, higher particulate matter and SO₂ were linked to more hospital presentations for lower respiratory diseases.¹¹ More recently, a Granger causality analysis conducted in Türkiye found that NO₂ and PM₁₀ levels causally preceded emergency department visits for URTI, asthma, and COPD, with peak pollutant concentrations in December and peak visits in January.²¹ In a time-series study from China, PM_{2.5}, NO₂, and SO₂ were each positively associated with hospital visits for acute URTI in adults, with SO₂ showing the largest single-lag effect at approximately five days.²² Overall, these findings support that common wintertime and urban pollutants can translate into a measurable respiratory burden at the community level.

In our dataset, pollutant effects varied by timing. SO₂ showed the clearest same-month association, indicating an immediate response during high-pollution periods. CO was also related to URTI in the same month but showed its strongest link with LRTI after two months. NO₂ displayed similar delayed patterns for both outcomes. Particulate matter was more consistently associated with LRTI, likely because lower respiratory infections are more severe and more reliably coded than URTI. Seasonal viral activity and care-seeking patterns may further dilute URTI signals. As monthly averages were used, these lags reflect general timing rather than exact delays.

Ozone behaved differently from combustion-related pollutants. URTI visits tended to be higher in months with lower O₃, although this was not statistically significant. Similar inverse patterns have been discussed in wintertime primary care analyses and are often attributed to seasonal chemistry: O₃ drops when sunlight is weak, while primary pollutants accumulate under stagnant conditions.¹⁴

Air pollution has been proposed as a short-term trigger for headache through several mechanisms, including airway and systemic inflammation, vascular effects, and neuroinflammatory pathways.^{2,12} However, the literature is not uniform about *which* pollutants matter most or *when* the effect appears. Some emergency department studies report increases in headache or migraine visits following rises in traffic-related gases (especially NO₂) and particulate matter within a few days,^{8,12} whereas other work suggests a broader, mixed-pollutant signal rather than one dominant agent.⁹ Differences in pollutant mixtures, weather, population vulnerability, and care-seeking behavior likely contribute to these inconsistencies. A 2024 narrative review similarly noted that short-term PM_{2.5} exposure

showed inconsistent associations with headache, whereas long-term exposure was more reliably linked to migraine prevalence and severity, underscoring the importance of exposure duration and temporal resolution in such analyses.²³

In our monthly primary care series, the main pattern was an inverse association between headache visits and ozone: headaches were more frequent in months with lower average O₃. This should not be read as ozone being “protective.” In Konya, lower ozone is typical of winter conditions with weaker sunlight and more stagnant air, which often overlaps with heating-related emissions and other seasonal factors that may influence headache presentations. This inverse pattern is consistent with the known seasonal chemistry of ozone and has been similarly noted in other ecological analyses of air pollution and headache.^{8,9,24} We also saw a delayed signal with particulate matter, with higher PM_{2.5} about two months earlier corresponding to more headache visits. Taking together, these findings suggest that headache presentations in primary care may reflect a seasonal context and possible short-term or delayed effects rather than a simple one-pollutant relationship.

Limitations

This study routinely collected primary care data from a single district in Konya and included only four family health centers; therefore, the findings may not generalize to regions with different demographics, pollution sources, or healthcare-use patterns. Because meteorological factors and seasonal viral activity were not analyzed, the results should be interpreted as ecological associations rather than causal effects, and winter conditions may have influenced both pollution levels and healthcare-seeking behavior. Analyses were based on monthly visit counts without individual-level variables limiting confounder adjustment. Furthermore, because the study relied on aggregated monthly visit counts rather than individual patient records, it was not possible to exclude patients with chronic conditions, pre-existing headache disorders (such as migraine), pregnancy, or sleep disturbances. These factors may independently influence healthcare-seeking behavior and could confound the observed associations, particularly for symptom-based outcomes such as headache and malaise/fatigue.

Exposure estimates relied on monthly averages from the nearest monitoring station, reflecting general ambient conditions but not individual exposure variability; such misclassification would more likely attenuate true associations. There are also inherent limitations to outcome recording. Subjective symptoms may be coded inconsistently, mild complaints may be overlooked, and there is diagnostic overlap between URTIs and LRTIs. Pneumonia was excluded because suspected cases are usually referred elsewhere. Monthly aggregation further prevented evaluation of short-term exposure–response patterns.

Malaise/fatigue is a broad and subjective complaint that can be influenced by many non-environmental factors (sleep, stress, intercurrent infections, chronic conditions), and it may be coded inconsistently in routine practice. Given this complexity, establishing causality between pollutant exposure and these symptom-based outcomes solely from ecological, monthly-level data constitutes a significant limitation of the present study. Headache is a multifactorial symptom influenced by numerous non-environmental triggers including psychological stress, sleep disturbance, hormonal factors, and medication use; therefore, any observed association between ambient pollutants and headache visits in this ecological study cannot be interpreted as evidence of causation. In addition, monthly averages smooth out day-to-day variability and can capture overlapping seasonal processes, which may contribute to apparent lagged patterns. Prospective studies with finer time resolution and individual-level data would be better suited to clarify whether the observed monthly associations reflect a true exposure–response relationship or broader seasonal clustering.

Conclusion

In this district-level primary care study, winter peaks in respiratory infection visits coincided with periods of higher ambient pollution, particularly combustion-related pollutants. The most consistent associations involved SO₂ and CO, with additional signals for NO₂ and particulate matter in lag analyses. These results highlight the value of primary care data for tracking community health effects of air pollution, especially during winter episodes. Future studies should incorporate multi-center data, daily time resolution, meteorological adjustments, and time-series lag models. Meanwhile, reducing winter emissions from heating and traffic and strengthening local early-warning and resource planning may help limit avoidable primary care demand and improve population health.

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Ethical statement: Ethical approval for this study was obtained from the KTO Karatay University Non-Interventional Research Ethics Committee (approval date: 26 February 2026; decision no: 2026/033).

Competing interest: The authors declare that they have no competing interests.

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