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RESEARCH ARTICLE / ÖZGÜN ARAŞTIRMA

The Relationship Between Ambient Air Pollution and Emergency Department Visits for Lower Respiratory Diseases: A Retrospective Cross-Sectional Study

Dış Ortam Hava Kirliliği ile Göğüs Hastalıkları Acil Başvuruları İlişkisinin Değerlendirilmesi: Retrospektif Kesitsel Bir Çalışma

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ABSTRACT

Objective: Air pollution reaches the systemic circulation in and through the lungs, causing a decrease in respiratory functions, respiratory tract infections, the development of asthma and chronic obstructive pulmonary disease, and an increase in exacerbations.There is no study in medical literature showing the relationship between air pollution and lower respiratory tract infection emergency service admissions in Ankara. This study aims to show the relationship between air pollution and the rate of Emergency Department Visits (EDVs) of patients with chest dieseases.

Material and Methods: This retrospective cross-sectional study was conducted in Ankara Atatürk Training and Research Hospital using medical records belonging to 302 EDVs for respiratory diseases. The data on ambient SO_2 and PM_{10} levels corresponding to the EDV dates were retrieved from the National Air Quality Monitoring Network website. The demographics and clinical data gathered from electronic files of patients were compared with the levels of air pollutants. Statistical analyses were performed using SPSS 20.0In the study, demographic characteristics, symptoms and diagnosis of the admission to the emergency department, arterial blood gase (pH, $PaCO_2$, PaO_2, SO_2), complete blood count, C-reactive protein and procalcitonin levels of the patients were examined.

Results: Among chest diseases EDVs, 11.6% of the patients had asthma, 33.1% chronic obstructive pulmonary disease, 13.9% pulmonary thrombo embolism, 44.7% pneumonia, 11.2% bronchiectasis, % 4 had interstitial lung disease, 2% had lung cancer and 44.7% had obstructive pulmonary disease. 87.7% of the patients presented with cough, 40.4% with sputum, 64.9% with shortness of breath, 37.4% with chest pain, 6% with hemoptysis and 27.8% with other symptoms. It was determined that SO_2 and PM_{10} levels, which are among the air pollutant parameters, were at the highest values in December at the time of admissions to the emergency service. Air pollution parameters were found to be significantly higher in patients with asthma, chronic obstructive pulmonary disease, pneumonia and obstructive pulmonary diseases compared to those without the disease ($p<0,05$). Air pollution parameters were found to be significantly higher in patients with cough, sputum, shortness of breath, and chest pain compared to those without these symptoms.

Conclusion: As the level of air pollution increases, the number of applications to the emergency room due to chest diseases increases and this is especially correlated with the increase in SO_2,

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PM_{10} and $PM_{2.5}$ levels.It was determined that the air pollution related triggering factors triggered the symptoms in patients who applied for chest diseases and that these factors are important factors in increasing the risk of chronic obstructive pulmonary disease, asthma and pneumonia.

Keywords: Air pollution, emergency department visits, PM_{10}, respiratory diseases, SO_2.

ÖZ

Amaç: Hava kirliliği, akciğerde ve akciğer aracılığıyla sistemik dolaşıma ulaşarak solunum fonksiyonlarında azalmaya, solunum yolu enfeksiyonlarına, astım ve kronik obstrüktif akciğer hastalığı gelişimine ve alevlenmelerin artışına sebep olur. Literatürde Ankara ilinde hava kirliliği ile alt solunum yolu enfeksiyonu acil servis başvurularını gösteren çalışma mevcut değildir. Bu çalışmada, acil servise başvuran göğüs hastalıkları bulunan hastaların başvuru oranlarının hava kirliliği ile ilişkisinin gösterilmesi amaçlandı.

Gereç ve Yöntemler: Çalışmaya, Ağustos 2018-Şubat 2019 tarihleri arasında Ankara Atatürk Eğitim ve Araştırma Hastanesi Acil Servisine göğüs hastalıkları konsültasyonu sonucunda primer pulmoner patoloji düşünülen hasta başvuruları alındı. Araştırmaya 302 hasta dahil edildi. Araştırmada hava kirliliği indikatörleri olarak SO_2, PM_{10} ve $PM_{2,5}$ seçildi. İndikatörlere ilişkin günlük veriler, T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'nın Hava Kalitesi İzleme İstasyonları web sitesinden alındı. Araştırmada hastaların demografik özellikleri, acil servise başvuru semptomları ve başvuru tanıları, arter kan gazı (pH, $PaCO_2$, PaO_2, SO_2), tam kan sayımı, C-reaktif protein ve prokalsitonin düzeyleri incelendi.

Bulgular: Göğüs hastalıkları acil başvurusunda hastaların %11,6'sı astım, %33,1'i kronik obstrüktif akciğer hastalığı, %13,9'u pulmoner tromboemboli, %44,7'si pnömoni, %11,2'si bronşiektazi, %4'ü interstisyel akciğer hastalığı, %2'si akciğer kanseri ve %44,7'si obstrüktif akciğer hastalığı tanılı idi. Hastaların %87,7'sinin öksürük, %40,4'ünün balgam, %64,9'unun nefes darlığı, %37,4'ünün göğüs ağrısı, %6'sının hemoptizi ve %27,8'inin diğer semptomlarla başvuru yaptıkları saptandı. Acil servise başvuruda aralık ayında hava kirletici parametrelerden SO_2, PM_{10} düzeylerinin en yüksek değerde olduğu saptandı. Astım, kronik obstrüktif akciğer hastalığı, pnömoni ve obstrüktif akciğer hastalıkları olanlarda olmayanlara kıyasla hava kirliliği parametresi/parametreleri anlamlı olarak daha yüksek saptandı ($p<0,05$). Öksürük, balgam, nefes darlığı, göğüs ağrısı olanlarda olmayanlara kıyasla hava kirliliği parametresi/parametreleri anlamlı olarak daha yüksek saptandı ($p<0,05$).

Sonuç: Hava kirliliği düzeyi arttıkça acil servise göğüs hastalıkları nedeniyle olan başvuru sayısı artmakta ve bu özellikle SO_2, PM_{10} ve $PM_{2,5}$ düzeyi artışıyla korelasyon göstermektedir. Hava kirliliğine bağlı tetikleyici faktörlerin göğüs hastalıkları nedeniyle başvuran hastalarda semptomları tetiklediği ve kronik obstrüktif akciğer hastalığı, astım ve pnömoni riskinin artmasında önemli bir faktör olduğu belirlendi.

Anahtar kelimeler: Acil başvuruları, hava kirliliği, PM_{10}, SO_2, solunum sistemi hastalıkları.

INTRODUCTION

Respiratory diseases, chronic obstructive pulmonary disease (COPD), lower respiratory infections, and pulmonary cancer are among the top causes of death that accounted for 55% of the 55.4 million deaths worldwide.[1] Environmental factors, particularly air pollution, have been associated with mortality and morbidity in respiratory diseases.[2–7] Considering the 91% of the global population that reside in locations with poor air quality, it is conceivable that ambient air pollution is one of the main factors in an estimated 4.2 million premature deaths.[8]

Among the common proxy indicators of air pollution, two of the strongest evidence for adverse health effects come from escalations of Sulfur dioxide (SO_2) and Particulate Matter, reported to be responsible for an increase in emergency department visits (EDVs) for respiratory diseases.[9–13] SO_2 is produced during domestic heating or combustion of fossil fuel in industrial settings. Coarse PM (PM_{10}), with a diameter between 2.5 and 10 μm, mainly occurs from construction work, industrial emissions, soil, and road dust resuspensions.[4,9,14–16] A strong relationship was found between asthma, COPD, and the higher levels of SO_2 and PM_{10}.[5,17–20]

Ambient air pollution has been recognized as a serious health problem in Turkey, a country with over 82 million population and dense urban centers, home to 98.9% of the total population.[21] Although the adverse effects of air pollution have been investigated in several studies from Turkey, data from Ankara, a highly urbanized and industrialized province, insufficient.[14,22–27] We hypothesized that the rates of respiratory diseases would increase when the levels of air pollutants escalate. We planned to conduct a study for a period including the warmer and colder months to observe the seasonal effects of air pollutants on human health as previously reported.[5,10,11,18]

To test our hypothesis in a cross-sectional study, we aimed to investigate the relationships between SO_2, PM_{10}, and lower respiratory diseases by retrospectively evaluating the records of EDVs in a third-level health-care facility in Ankara and analyze the data by comparing with air pollutant levels corresponding to the dates of EDVs.

MATERIAL AND METHODS

Study Design and Setting

This retrospective and analytical cross-sectional study was conducted in Ankara Atatürk Training and Research Hospital, a 500-bed tertiary care facility with an annual 45,000 EDVs. Ankara, with 25.632 km^2 of land and 5.445 million population, is the second largest city and the capital of Turkey that is highly urbanized and industrialized.[28] Air pollution, which is the main problem of Ankara, especially in winter, stems from sources such as public transport, domestic heating, and industrial settings. Moreover, its geographic location in central Anatolia and surrounded by mountains on three sides is not favorable for air circulation, which leads to the hovering of harmful pollutants above the city.[29,30]

Participant Inclusion and Exclusion Criteria

After screening the medical records belonging to the EDVs of consecutive cases who presented with respiratory complaints between August 2018 and January 2019, the demographic and clinical data of patients diagnosed with lower respiratory diseases by the consultant pulmonologist were included in the study. The diagnosed lower respiratory diseases consisted of asthma, COPD, pulmonary thromboembolism, pneumonia, bronchiectasis, interstitial lung disease, lung cancer, and asthma-COPD overlap (ACO).

The patients younger than 18 years, without a diagnosis of lower respiratory disease, and with missing medical or air pollution data relevant to the study were excluded. The multiple EDVs with the same diagnosis during the study period were not included.

Ethical Statement

The study, which was designed in accordance with the amended Declaration of Helsinki, Good Clinical Practice guidelines, and the Patient Rights regulations, was approved by the Ethics Committee of Ankara Yildirim Beyazit University Faculty of Medicine (Number: 66, Date: 05/29/2019). Data gathered were anonymized before the analyses.

Data sources and variables for analysis

The electronic medical files of patients were retrieved from the hospital archive system and relevant data were gathered from the records. The demographical and clinical data consisted of age, gender, location of residency, the EDV date and presenting symptoms, smoking status, co-morbidities, the diagnosis by the pulmonologist and outcome of EDV, and laboratory results including complete blood count, C-reactive protein (CRP), procalcitonin (PCT), and arterial blood gases (pH, pCO_2, pO_2, sO_2) that were part of the routine investigations policy for all patients with respiratory complaints in our ED. The one-month mortality records were obtained from the institutional mortality report system.

The proxy pollutants selected for the current study were SO_2 and PM_{10}, and their 24-hour average concentrations on the dates corresponding to the EDVs and from the station closest to the residency of the patients were acquired from the database of National Air Quality Monitoring Network (NAQMN).[31]

The acquired pollutant data was handled in monthly clusters for analysis purposes. The relationship between the investigated variables of EDVs and pollutants were analyzed for SO_2 and PM_{10} separately in general and in subgroups categorized according to the critical threshold levels (SO_2:20 $\mu g/m^3$ and PM_{10}:40 $\mu g/m^3$) as reported in NAQMN webpage.[32]

The possibility of recall bias was eliminated by the study design, which depended on gathering data from officially written records, in addition to reviewing the accuracy by at least two coauthors of the study. The possibility of selection bias was avoided by conducting the study on consecutive cases meeting the eligibility criteria and without any stratification. The cases with a lack of data relevant for the study were excluded to minimize the information bias.

The primary outcome measure had been set as the number of monthly EDVs for lower respiratory diseases in relation to the mean SO_2 and PM_{10} levels. The secondary outcome measure had been set as the distribution of demographic and clinical data in relation to the mean SO_2 and PM_{10} levels.

Statistical analysis

Statistical Package for Social Sciences (SPSS) for Windows Version 20.0 (IBM SPSS Inc., Chicago, IL) was used for statistical analyses. The normal distribution of data was evaluated using the Kolmogorova-Smirnov test. The numerical variables with normal distribution were expressed as mean±standard deviation and the ones without normal distribution were expressed as median and interquartile range (minimum-maximum). The categorical variables were expressed as numbers and frequencies. The comparison of numerical variables was analyzed using the t-test or the Mann-Whitney U-test. The ANOVA or Kruskall Wallis H tests were used for comparing numerical variables among three or more groups. Categorical variables were compared via Chi-square and Fisher's exact tests. Pearson correlation test was performed to determine the relationship between pollutants and laboratory test results. A p-value below 0.05 was considered statistically significant.

RESULTS

A total of 327 ED patients who were diagnosed with a pulmonary disease were identified to be eligible for the study period of six months. Twenty-five cases in which the air pollutant data could not be acquired from the monitoring station relevant for the patient were excluded. The study was completed with 302 patients confirmed eligible.

The mean age of patients was 68.9±15.8 years (min-max: 21–95). The majority of the group were ≥65 years (64.6%), male (59.9%), and former smokers (51.7%). The majority of the EDVs were patients from Sincan (59.3%). Following the EDV, approximately one-fourth of patients (25.8%) were admitted to the intensive care unit (ICU), while 34.4% were followed up as an outpatient. The general mortality rate was estimated as 12.3%. The ICU admission

Table 1: The distribution of demographic and clinical data in relation to the air pollutants

Demographic information	Overall		SO_2 (μg/m³) n=302		p	SO_2 (μg/m³) n=302				p	PM_{10} (μg/m³)				p
						<20		≥20			<40		≥40		
	n	%	Min	Max		n	%	n	%		n	%	n	%	
Age, Mean±SD	68.9±15.8					67.4±16.3		69.5±14.2		0.322	66.6±16.5		68.7±15.4		0.270
<65 years	107	35.4	9.6	1.5–48.1	0.048*	86	37.6	21	28.8	0.172	46	41.1	61	32.1	0.116
≥65 years	195	64.6	13.8	1.8–122		143	62.4	52	71.2		66	58.9	129	67.9	
Gender															
Male	181	59.9	11.7	1.5–122	0.814	135	59.0	46	63.0	0.537	60	53.6	121	63.7	0.083
Female	121	40.1	12.4	2.0–75.7		94	41.0	27	37.0		52	46.4	69	36.3	
Smoking															
Current	31	10.3	15.8	2.2–48.1	0.76	21	9.2	10	13.7	0.655	9	8.0	22	11.6	0.207
Former	156	51.7	11.7	1.8–122		121	52.8	35	47.9		52	46.4	104	54.7	
Never	100	33.1	11.9	2.0–75.7		75	32.8	25	34.2		45	40.2	55	28.9	
Unknown	15	5.0	14.6	1.5–44.1		1	5.2	3	4.1		6	5.4	9	4.7	
Station															
Sincan	179	59.3	11.4	1.5–122	0.717	132	57.6	47	64.4	0.618	76	67.9	103	54.2	0.396
Demetevler	20	6.6	12.7	2.0–44.1		13	5.7	7	9.6		6	5.4	14	7.4	
Kayaş	5	1.7	7.5	4.8–48.1		4	1.7	1	1.4		2	1.8	3	1.6	
Sıhhıye	11	3.6	11.1	5.0–23.7		10	4.4	1	1.4		4	3.6	7	3.7	
Bahçelievler	47	15.6	13.8	4.0–75.7		39	17.0	8	11.0		13	11.6	34	17.9	
Keçiören	12	4.0	16.5	6.0–35.1		9	3.9	3	4.1		4	3.6	8	4.2	
Diğerleri	28	9.3	15.8	3.0–34.5		22	9.6	6	8.2		7	6.3	21	11.1	
Month															
August	12	4.0	4.2	2.6–5.9	<0.001*	12	5.2	–		<0.001*	7	6.2	5	2.6	<0.001*
September	52	17.2	7.1	1.8–15.2		52	22.7	–			46	41.1	6	3.2	
October	40	13.2	11.1	3.3–43.6		38	16.6	2	2.7		12	10.7	28	14.7	
November	44	14.6	16	1.5–44.1		39	17.0	5	6.8		9	8.0	35	18.4	
December	120	39.7	20.7	2.0–122		60	26.2	60	82.2		27	24.1	93	48.9	
January	34	11.3	9.6	3.6–44.6		28	12.2	6	8.2		11	9.8	23	12.1	
Outcome															
Outpatient	104	34.4	12	2.2–48.2	0.681	80	34.9	24	32.9	0.79	38	33.9	66	34.7	0.453
Inpatient	120	39.7	11.3	1.8–75.7		92	40.2	28	38.4		49	43.8	71	37.4	
ICU	78	25.8	13.7	1.5–122		57	24.9	21	28.8		25	22.3	53	27.9	
Mortality															
Yes	37	12.3	15.8	4.2–122.0	0.069	203	88.6	62	84.9	0.415	102	91.1	163	85.8	0.206
No	265	87.7	11.5	1.5–75.6		–		–			–		–		

*Statistically significant. SO_2: Sulfur dioxide, PM_{10}: Particulate matter 10, ICU: Intensive care unit, SD: Standard deviation, Min: Minimum, Max: Maximum.

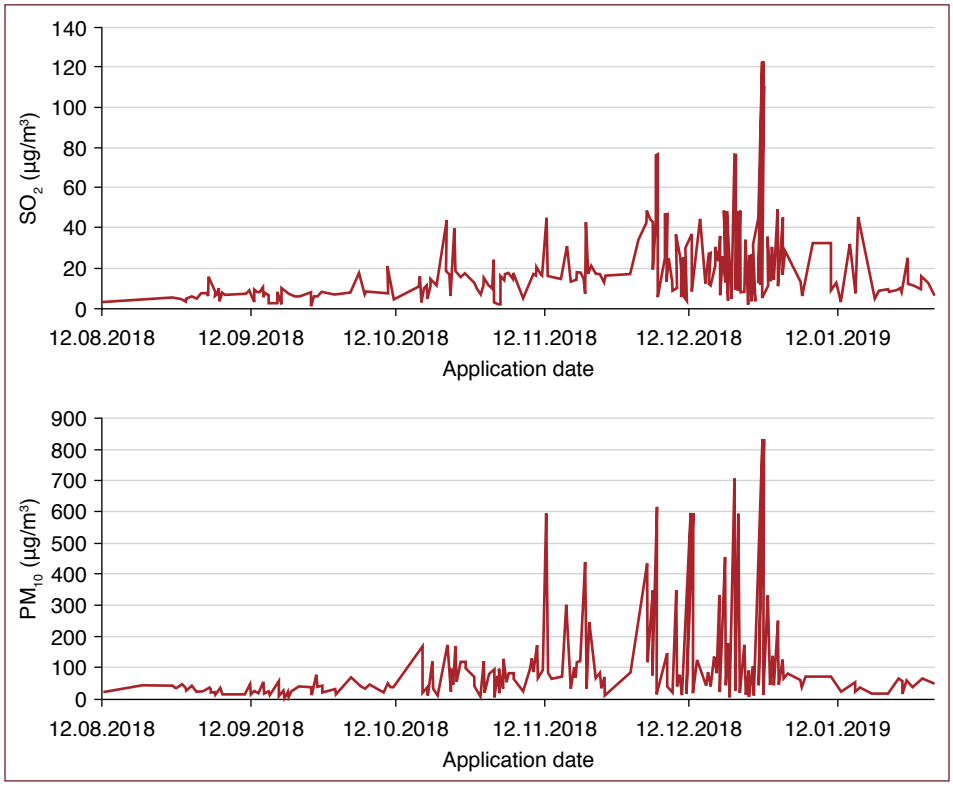


Figure 1: Distribution of SO_2 ve PM_{10} levels by application date.

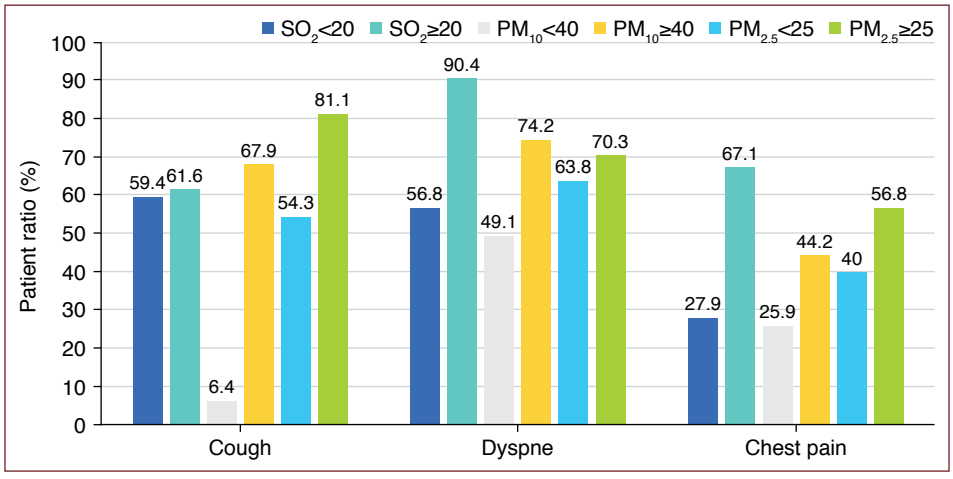


Figure 2: Distribution of symptoms in emergency admission according to the critical levels of air pollution.

and mortality rates in patients ≥65 (30.3% and 16.4%, respectively) were significantly higher than those in patients <65 (17.8% and 4.7%, respectively). (p=0.045 and p=0.003, respectively). Table 1 summarizes the demographical data (Table 1).

The median SO_2 and PM_{10} values in Ankara during the 6-month study period were 11.7 $\mu g/m^3$ (min-max: 1.5–122) and 49.1 $\mu g/m^3$ (min-max: 10.8–831), respectively. The median SO_2 exposure in patients ≥65 years (13.8 $\mu g/m^3$) was significantly higher than that of the patients <65 years (9.6 $\mu g/m^3$) (p=0.048). The number of EDVs was the greatest in December (n=120, 39.7%) when the median SO_2 (20.7 $\mu g/m^3$) and PM_{10} (80.8 $\mu g/m^3$) were significantly higher than their values in other months (p<0.001) (Fig. 1). The rate of EDVs in December was significantly higher in patients exposed to higher than threshold (HTT) SO_2 (82.2%) and PM_{10} (48.9%) when compared with the patients (26.2% and 24.1%, respectively) exposed to lower than threshold (LTT) (p<0.001) (Table 1).

The most common presenting symptom was cough in 87.7% of the patients. The median SO_2 (11.5 $\mu g/m^3$) and PM_{10} (46.7 $\mu g/m^3$) that the patients with cough exposed to were significantly higher than the values the patients without cough exposed (p<0.001 and p=0.002, respectively). The other symptoms that were significantly related to higher median SO_2 and PM_{10} included phlegm, dyspnea, and chest

Table 2: The distribution of presenting symptoms in relation to the air pollutants

Symptom	Overall		SO_2 (μg/m³) median			p	SO_2 (μg/m³) n=302				p	PM_{10} (μg/m³) median		p	PM_{10} (μg/m³) n=302				p
							<20		≥20						<40		≥40		
	n	%	Min	Max			n	%	n	%		Min	Max		n	%	n	%	
Cough																			
Yes	265	87.7	11.5	1.5–75.6	<0.001*		93	40.6	28	38.4	0.732	46.7	10.8–607	0.002*	60	53.6	61	32.1	<0.001*
No	121	40.1	9.1	1.8–33.4			–		–			40	11.4–263		–		–		
Phlegm																			
Yes	122	40.4	15.7	1.5–122	<0.001*		143	62.4	37	50.7	0.077	63.1	10.8–831	<0.001*	79	70.5	101	53.2	0.003*
No	180	59.6	10.1	1.8–48.2			–		–			41	11.5–594		–		–		
Dyspnea																			
Yes	196	64.9	15.8	1.5–122	<0.001*		99	43.2	7	9.6	<0.001*	65.6	10.8–831	<0.001*	57	50.9	49	25.8	<0.001*
No	106	35.1	9.1	1.8–33.4			–		–			34.1	11.4–169		–		–		
Chest pain																			
Yes	113	37.4	17.2	1.5–75.7	<0.001*		165	72.1	24	32.9	<0.001*	72.7	10.8–698	<0.001*	83	74.1	106	55.8	0.001*
No	189	62.6	10.9	1.8–122			–		–			41.8	11.4–831		–		–		
Hemoptysis																			
Yes	18	6.0	13.7	2.2–43.1	0.929		217	94.8	67	91.8	0.514	61.3	11.8–594	0.482	105	93.8	179	94.2	0.999
No	284	94.0	11.7	1.5–122			–		–			48.1	10.8–831		–		–		
Other																			
Yes	84	27.8	12	2.2–122	0.268		161	70.3	57	78.1	0.231	44.4	11.5–831	0.069	80	71.4	138	72.6	0.822
No	218	72.2	11.7	1.5–75.7			–		–			53.4	10.8–698		–		–		

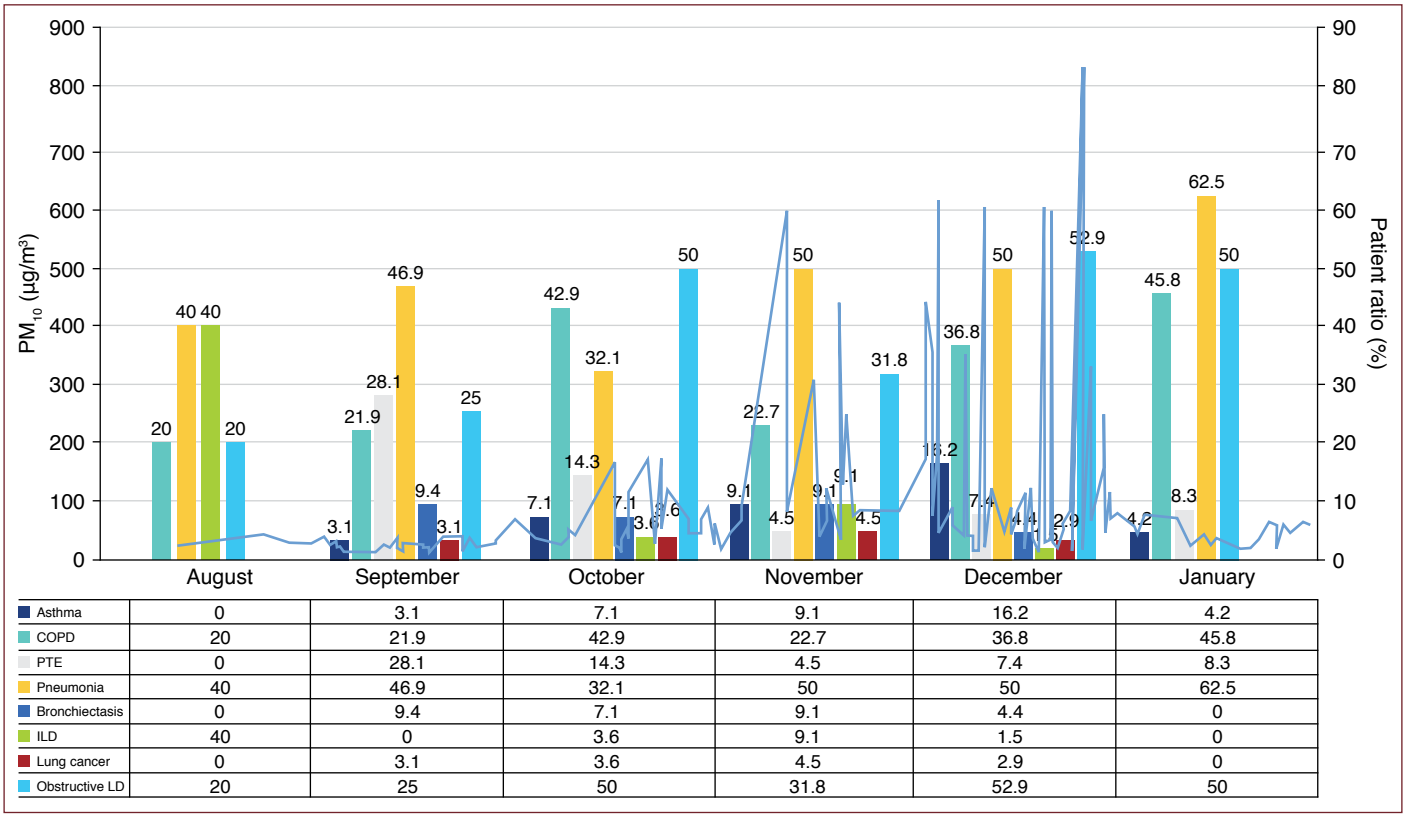
*Statistically significant. SO_2: Sulfur dioxide, PM_{10}: Particulate matter 10, Min: Minimum, Max: Maximum.

pain (p<0.001 for each). There were significant relationships between the HTT SO_2 levels and the rate of patients presented with dyspnea (90.4%) and chest pain (67.1%) (p<0.001), as well as between the HTT PM_{10} levels and the rate of patients presented with cough (67.9%, p<0.001), phlegm (46.8%, p=0.003), dyspnea (74.2%, p<0.001), and chest pain (44.2%, p=0.001) (Table 2) (Fig. 2).

The two most common diagnoses in the study were pneumonia (44.7%) and ACO (44.7%). The rate of COPD (36.9%) in patients ≥65 years were significantly higher than that in patients <65 years (26.2%) (p=0.05), while the rates of asthma (8.7%) and bronchiectasis (2.1%) were significantly lower than those in patients <65 years (16.8% and 10.3%, respectively) (p=0.04 and p=0.004, respectively). The diagnoses of COPD and pneumonia were significantly higher in cases from the Sincan area and exposed to significantly higher levels of SO_2 (11.4 μg/m³) and PM_{10} (44.3 μg/m³) in December compared to other months (p<0.001) (Figs. 3, 4). The median SO_2 in COPD (15.5 μg/m³) and pneumonia (15.4 μg/m³) cases were significantly higher than the cases without those diagnoses (p=0.033 and p=0.020, respectively), while the median PM_{10} in asthma (64.3 μg/m³), COPD (63.1 μg/m³), pneumonia (57.8 μg/m³), and ACO (58.6 μg/m³) were significantly higher than the patients without those diagnoses (p=0.22, p<0.001, p=0.028, and p=0.048, respectively). There were significant relationships between the HTT SO_2 and the rate of patients with COPD (43.8%, p=0.032) and pneumonia (58.9%, p=0.034), and between the HTT PM_{10} and the rate of patients with COPD (37.9%, p=0.021) and pneumonia (48.9%, p=0.045) (Table 3).

The comorbid conditions in the study group consisted of atherosclerotic heart disease (ASHD) (39.4%), heart failure (24.8%), hypertension (51%), diabetes mellitus (17.5%), neurologic disorders (15.6%), and others (20.9%). No relationships were found between any comorbidity and the levels of air pollutants (p>0.05); however, we found a significant relationship between the HTT SO_2 and the rate of patients with ASHD (50.7%, p=0.047).

There was a significant relationship between the HTT SO_2 and the higher mean blood pH (7.5±0.1) compared to the pH (7.4±0.1) in patients exposed to LTT SO_2 (p=0.039). There were a significant correlations between the HTT PM_{10} and mean CRP (69.6 mg/l) and mean PCT (0.5 ng/ml) compared to the CRP



	August	September	October	November	December	January
Asthma	0	3.1	7.1	9.1	16.2	4.2
COPD	20	21.9	42.9	22.7	36.8	45.8
PTE	0	28.1	14.3	4.5	7.4	8.3
Pneumonia	40	46.9	32.1	50	50	62.5
Bronchiectasis	0	9.4	7.1	9.1	4.4	0
ILD	40	0	3.6	9.1	1.5	0
Lung cancer	0	3.1	3.6	4.5	2.9	0
Obstructive LD	20	25	50	31.8	52.9	50

Figure 3: Distribution of PM_{10} levels (line graph) and lung diseases (column graph) in Sincan region by date of application.

PM_{10}: Particulate matter 10, COPD: Chronic obstructive pulmonary disease, PTE: Pulmonary Thromboembolism, ILD: Interstitial Lung Diseases, LD: Lung Diseases.

(45 mg/l) and procalcitonin levels (0.2 ng/ml) in patients exposed to LTT SO_2 (p=0.029, p=0.033, and p=0.029, respectively).

The levels of SO_2 significantly correlated with the levels of PM_{10} (r:0.827, p<0.001). The analyses demonstrated significant correlations between the SO_2 levels and mean blood pH (r:0.312, <0.001), pCO_2 (r:0.344, p<0.001), pO_2 (r: –0.931, p<0.001), COHb (r: 0.296, p=0.039), CRP (r: 0.296, p=0.047), and PCT (r: 0.394, p=0.013). There was a significant correlation between the PM_{10} and PCT (r: 0.305, p=0.013) (Table 4).

DISCUSSION

The present study provided support to our hypothesis about the presence of a relationship between the number of EDVs for respiratory diseases and the levels of air pollution, based on our observation of a significant number of EDVs for lower respiratory diseases in December (39.7%), when the median SO_2 (20.7 $\mu g/m^3$) and PM_{10} (80.8 $\mu g/m^3$) were significantly higher than the other months (p<0.001). The subgroup analyses also indicated that the HTT SO_2 and PM_{10} exposure was significantly related to 120 cases of EDVs in December. Overall, the median SO_2 and PM_{10} values in our study (11.7 and 49.1 $\mu g/m^3$, respectively) were close to the values recently reported for Ankara (10.6 and 62.2 $\mu g/m^3$, respectively).[25] Consistent with our results, an escalation in the number of hospital admissions for respiratory diseases due to increased concentrations of SO_2 and PM_{10} had been observed in various studies from Turkey.[22–25]

In some study designs, lag days were incorporated for analyzing the time effect of air pollution on respiratory diseases. While some studies reported the worse adverse effects at lag days ranging between 0 and 2,[11,13] some others reported that no consistent evidence for lagging was present for lower respiratory diseases.[20] Recently, a study from Turkey pointed out the impact of air pollution on EDVs within ten day post-exposure.[22] Here, we did not employ a design considering lag days, instead analyzed the results in monthly clusters. Thus, a relationship between an increase in the monthly median concentration of air pollutants and the EDV numbers must be interpreted as the reflection of a general picture of the incidents without fine-tuning.

The vulnerability of people ≥65 years to the effects of air pollution had been reported previously in many studies.[10,11,24,25] Consistently, the age-stratified analysis showed that patients ≥65 were significantly exposed to higher median SO_2 (13.8 $\mu g/m^3$) corresponding to the dates of their EDVs. Moreover, in our study, the mean age of the patients was 68.9±15.8 years, and 64.6% of the cases were ≥65 in our study. As our study design does not allow to establish a causative effect besides uncontrolled age-related confounding factors, our observation of the statistically significant higher rates of ICU admission (30.3%) and mortality (16.4%) in patients ≥65 years could be interpreted as a tendency for an increase in age and negative impacts of ambient air pollution.

Another research subject is the effects of air pollutants on the seasonality of hospital admissions for respiratory diseases.[6,11,12] Recent studies indicated peak numbers of EDVs and hospital ad-

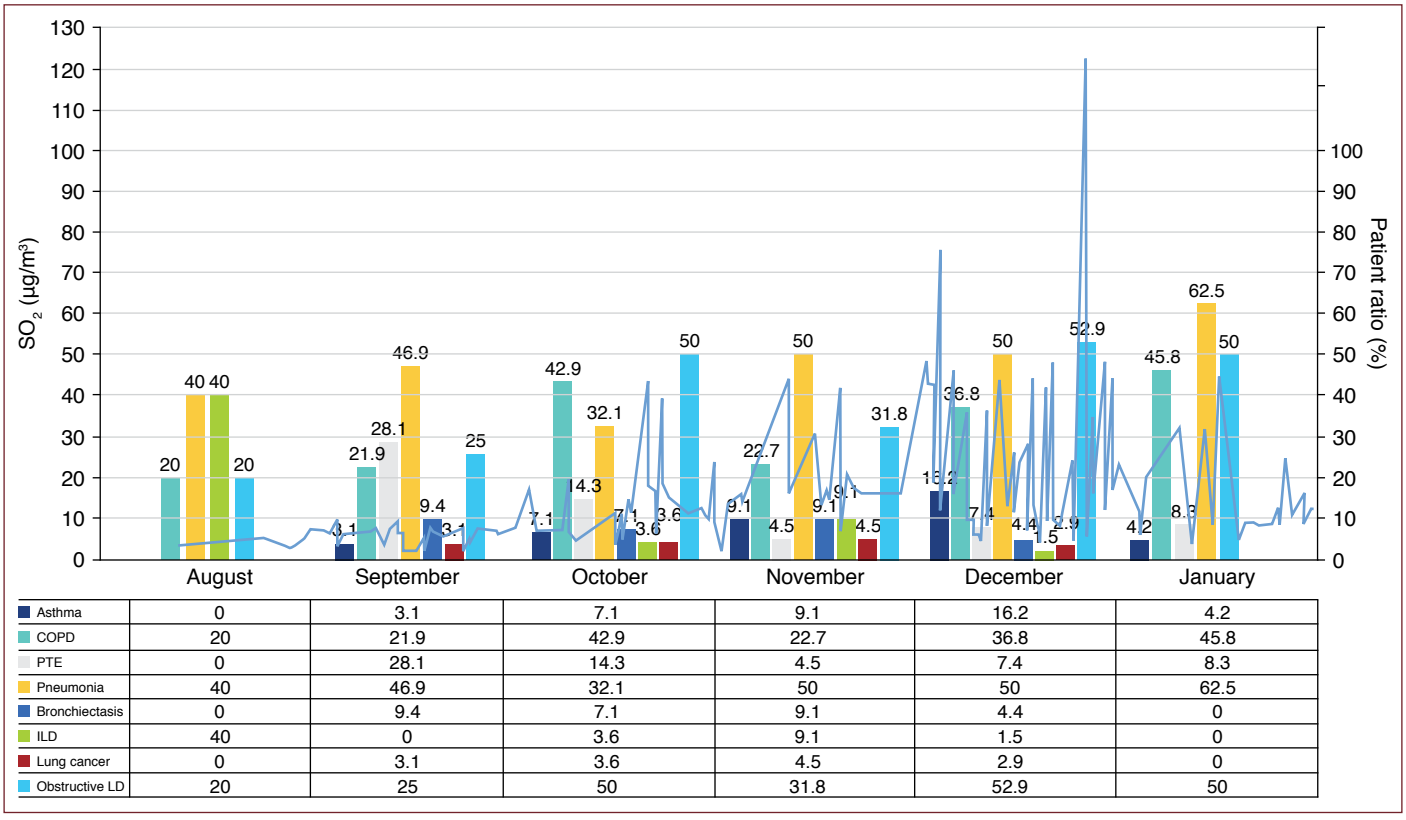


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Figure 4: Distribution of SO_2 levels (line graph) and lung diseases (column graph) in Sincan region by date of application.

SO_2: Sulfur dioxide, COPD: Chronic obstructive pulmonary disease, PTE: Pulmonary Thromboembolism, ILD: Interstitial Lung Diseases, LD: Lung Diseases.

missions for respiratory diseases associated with escalated air pollution during the colder winter months.[6,10,11] Consistently, more than half of the EDVs (198 out of 302) in the current study were between November and January, corresponding to the cold season in Ankara. Moreover, ambient concentrations of SO_2 and PM_{10} were maximum in these months.[33] Respiratory diseases, such as asthma and pneumonia in colder months, were associated with air pollution in Turkey.[25,27] In some of the studies, different air pollutants were evaluated separately. For example, pneumonia in patients ≥65 in colder months was associated with the high levels of PM_{10} but not with SO_2.[25]

The current study indicated that EDVs for pneumonia and COPD were both related with higher SO_2 and PM_{10}, while PM_{10} was significantly higher in EDVs for asthma and ACO. The association between respiratory diseases and the ambient concentrations of SO_2 and PM_{10} was not consistent among the studies. For example, pneumonia was associated with PM_{10} but SO_2 in two recent studies.[5,34] Contrarily, Soleimani et al.[17] reported an association between pneumonia and SO_2. Yet, in another study, pneumonia EDVs were associated with none of the air pollutants.[18] In some studies, an association between SO_2 and asthma was found,[35] while in others and similarly to our results, no association was detected.[12,17,26] Previously and consistent with our observations, positive associations between higher SO_2 and PM_{10} concentrations and COPD exacerbations were reported.[5,17,18,26,33] It should be noted that discrimination between a new diagnosis vs exacerbation of COPD was not possible due to the design of our study. On the other hand, we observed significant correlations between SO_2 and PM_{10} and the PCT values, which were previously associated with disease severity in acute exacerbations of COPD and pneumonia.[36–38] Higher levels of SO_2 and PM_{10} were associated with higher incidents of asthma and chronic bronchitis.[14] The most common diagnosis in EDVs was pneumonia (44.7%), which was different than the results by Soleimani et al.,[17] who found the most reported disease in their study was COPD. The discordance of results for the relationship between air pollutants and respiratory diseases was attempted to be explained by different median levels of ambient pollutants in various study locations.[7] Additionally, Wang et al.[19] argued against the direct effect of SO_2 and, based on its significant correlation with the presence of other pollutants in their study, suggested its association when adjusted for multiple-pollutant models. Consistent with the previous reports, we observed a positive correlation between the concentrations of SO_2 and PM_{10}.[7,26,33] We noticed that whenever a significant relationship with SO_2 was observed, the same variable also had a significant relationship with PM_{10}. In spite of the significant correlation observed between SO_2 and PM_{10}, the explanation for the difference in the individual effects of each pollutant on the number of EDVs for different diagnoses in our and other studies exceeds the limits and the aim of the current study.

When we analyzed the presenting symptoms of patients to ED, a significant relations between SO_2 and PM_{10} levels and four major symptoms (cough, phlegm, dyspnea, chest pain) were found, which was similar to the previous studies.[39,40] Further analysis regarding the threshold levels indicated that HTT PM_{10} but SO_2 were related

Table 3: The distribution of diagnoses in relation to the air pollutants

Diagnosis	Overall		SO_2 (μg/m³) median		p	SO_2 (μg/m³) n=302				p	PM_{10} (μg/m³) median		p	PM_{10} (μg/m³) n=302				p
						<20		≥20						<40		≥40		
	n	%	Min	Max		n	%	n	%		Min	Max		n	%	n	%	
Asthma																		
No	267	88.4	12.3	1.5–122	0.503	28	12.2	7	9.6	0.676	50.3	10.8–698	0.022*	14	12.5	21	11.1	0.713
Yes	35	11.6	9.6	3.3–30.1		–		–			64.3	11.6–831		–		–		
COPD																		
No	202	66.9	11	1.5–122	0.033*	68	29.7	32	43.8	0.032*	44.5	11.4–831	<0.001*	28	25.0	72	37.9	0.021*
Yes	100	33.1	15.5	2.2–75.7		–		–			63.1	10.8–698		–		–		
Pulmonary thromboembolism																		
No	260	86.1	13.2	1.5–122	0.103	34	14.8	8	11.0	0.445	53.1	10.8–831	0.075	22	19.6	20	10.5	0.098
Yes	42	13.9	10.7	1.8–33.4		–		–			45.7	11.8–263		–		–		
Pneumonia																		
No	167	55.3	11.2	1.8–75.7	0.020*	92	40.2	43	58.9	0.034*	44.2	10.8–698	0.028*	42	37.5	93	48.9	0.045*
Yes	135	44.7	15.4	1.5–122		–		–			57.8	11.5–831		–		–		
Bronchiectasis																		
No	287	95.0	11.7	1.5–122	0.324	13	5.7	2	2.7	0.486	47.1	10.8–831	0.99	5	4.5	10	5.3	0.972
Yes	15	5.0	11.2	2–33.4		–		–			55.3	11.4–169		–		–		
Interstitial lung disease																		
No	290	96.0	12	1.5–122	0.329	10	4.4	2	2.7	0.783	48.1	10.8–831	0.828	3	2.7	9	4.7	0.562
Yes	12	4.0	10.4	3–36.2		–		–			56.3	11.5–594		–		–		
Lung cancer																		
No	296	98.0	11.7	1.5–122	0.762	5	2.2	1	1.4	0.999	48.1	10.8–831	0.494	1	0.9	5	2.6	0.536
Yes	6	2.0	16.5	4–30		–		–			58.3	35.2–121		–		–		
ACO																		
No	167	55.3	11.2	1.5–122	0.113	101	44.1	34	46.6	0.712	44.9	11.4–831	0.048*	47	42.0	88	46.3	0.463
Yes	135	44.7	14	2.2–75.7		–		–			58.6	10.8–698		–		–		

*Statistically significant. SO_2: Sulfur dioxide, PM_{10}: Particulate matter 10, COPD: Chronic obstructive pulmonary disease, ACO: Asthma- COPD Overlap, Min: Minimum, Max: Maximum.

Table 4: The correlations between laboratory test results and air pollutants

	SO_2 (μg/m³)		PM_{10} (μg/m³)	
	r	p	r	p
PM_{10}	0.827	<0.001*	-	-
pH	0.312	<0.001*	0.159	0.099
pCO_2	0.344	<0.001*	0.016	0.783
pO_2	0.931	<0.001*	0.009	0.880
Saturation	0.134	0.156	0.136	0.153
COHb	0.296	0.039*	0.093	0.192
Hb	0.082	0.156	0.026	0.653
RDW	0.303	0.001*	0.297	0.005*
WBC	0.158	0.315	0.034	0.558
CRP	0.296	0.047*	0.089	0.128
Procalcitonin	0.394	0.013*	0.305	0.013*

*Statistically significant. SO_2: Sulfur dioxide, PM_{10}: Particulate matter 10, pH: Negative of the base 10 logarithm of the molar concentration of hydrogen ions in the solution, pCO_2: Partial pressure of carbon dioxide, pO_2: Partial pressure of oxygene, COHb: Carboxyhemoglobin, Hb: Hemoglobin, RDW: Red cell distribution width, WBC: White blood count, CRP: C-reactive protein.

to cough and phlegm, which was consistent with a previous study.[39] No respiratory symptoms were associated with air pollutants in another Turkish study.[14] The symptoms of respiratory diseases are mostly not specific to one disease, and overlaps are common; on top of that, the frequency of symptoms varies with the escalations in air pollution.[41]

The strengths and limitations of the study should be addressed. To the best of our knowledge, this is the first study that investigated the effects of air pollution on multiple lower respiratory diseases rather than focusing on a single disease. Secondly, the inclusion of a diverse group of patients regarding age, gender, comorbidity, and smoking status allowed us to minimize the confounding bias. The location and credentials of our hospital with an annual patient volume higher than many tertiary hospitals in the area allowed our results to reflect the population in the central Anatolia to an important extent. The limitations of the study include the collection of ambient air pollution data from fixed-site monitoring stations, which could lead to measurement errors out of our control. The lack of measuring other environmental factors, such as air temperature and other ambient air pollutants, is another limitation. The rate of EDVs for respiratory diseases might underestimate the extent of the population affected by the pollutants because outpatient clinics for respiratory diseases are also convenient options in the Turkish health-care system for patients with respiratory complaints. Although our hospital serves a large area, as mentioned before, still the conduction of the study in a single center may lead to sampling bias and limit the generalisability. The short study period of six months restricted to test for all seasonal trends in a year relevant to the study. The cross-sectional design of the study restricted the analyses for longitudinal effects of pollutants.

CONCLUSION

The significant relationship between escalations in ambient SO_2 and PM_{10} and increased EDVs for lower respiratory diseases observed in this retrospective cross-sectional study indicated that air pollution in Ankara continues to be a critical health problem.

Disclosures

Ethics Committee Approval: The study was approved by The Yildirim Beyazit University Faculty of Medicine Clinical Research Ethics Committee granted approval for this study (date: 29.05.2019, number: 66).

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – B.Ö., M.E.; Design – B.Ö., M.E., H.C.H.; Supervision – H.C.H., B.Ö., M.E.; Fundings – B.Ö.; Materials – B.Ö., M.E.; Data Collection and/or Processing – B.Ö.; Analysis and/or Interpretation – B.Ö., M.E., H.C.H.; Literature Search – B.Ö., M.E.; Writing – B.Ö.; Critical Reviews – B.Ö., M.E., H.C.H.

Conflict of Interest: The authors have no conflict of interest to declare.

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REFERENCES

1. World Health Organization. The top 10 causes of death. Available at: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death. Accessed Mar 15, 2022.
2. Bonyadi Z, Arfaeinia H, Fouladvand M, Farjadfard S, Omidvar M, Ramavandi B. Impact of exposure to ambient air pollutants on the admission rate of hospitals for asthma disease in Shiraz, southern Iran. Chemosphere 2021;262:128091.
3. Croft DP, Zhang W, Lin S, Thurston SW, Hopke PK, Masiol M, et al. The association between respiratory infection and air pollution in the setting of air quality policy and economic change. Ann Am Thorac Soc 2019;16:321–30.
4. Khaniabadi YO, Sicard P, Takdastan A, Khaniabadi FO, Marco A, Daryanoosh M. Mortality and morbidity due to ambient air pollution in Iran. Clin Epidemiology Glob Health 2019;7:222–7.
5. Pothirat C, Chaiwong W, Liwsrisakun C, Bumroongkit C, Deesomchok A, Theerakittikul T, et al. Acute effects of air pollutants on daily mortality and hospitalizations due to cardiovascular and respiratory diseases. J Thorac Dis 2019;11:3070–83.
6. Zhang Z, Chai P, Wang J, Ye Z, Shen P, Lu H, et al. Association of particulate matter air pollution and hospital visits for respiratory diseases: A time-series study from China. Environ Sci Pollut Res Int 2019;26:12280–7.
7. Cheng Y, Ermolieva T, Cao GY, Zheng X. Health impacts of exposure to gaseous pollutants and particulate matter in beijing-a non-linear analysis based on the new evidence. Int J Environ Res Public Health 2018;15:1969.
8. World Health Organization. 2016. Ambient air pollution. Available at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/ambient-air-pollution. Accessed Mar 15, 2022.
9. Bălă GP, Râjnoveanu RM, Tudorache E, Motișan R, Oancea C. Air pollution exposure-the (in)visible risk factor for respiratory diseases. Environ Sci Pollut Res Int 2021;28:19615–28.

10. Song X, Jiang L, Wang S, Tian J, Yang K, Wang X, et al. The impact of main air pollutants on respiratory emergency department visits and the modification effects of temperature in Beijing, China. Environ Sci Pollut Res Int 2021;28:6990–7000.
11. Ma Y, Yang S, Zhou J, Yu Z, Zhou J. Effect of ambient air pollution on emergency room admissions for respiratory diseases in Beijing, China. Atmos Environ 2018;191:320–7.
12. Chang JH, Hsu SC, Bai KJ, Huang SK, Hsu CW. Association of time-serial changes in ambient particulate matters (PMs) with respiratory emergency cases in Taipei's Wenshan District. PLoS One 2017;12:e0181106.
13. Chen G, Zhang Y, Zhang W, Li S, Williams G, Marks GB, et al. Attributable risks of emergency hospital visits due to air pollutants in China: A multi-city study. Environ Pollut 2017;228:43–9.
14. Mentese S, Bakar C, Mirici NA, Oymak S, Otkun MT. Associations between respiratory health and ambient air quality in Canakkale, Turkey: A long-term cohort study. Environ Sci Pollut Res Int 2018;25:12915–31.
15. Schwarze PE, Ovrevik J, Låg M, Refsnes M, Nafstad P, Hetland RB, et al. Particulate matter properties and health effects: Consistency of epidemiological and toxicological studies. Hum Exp Toxicol 2006;25:559–79.
16. World Health Organization. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005: Summary of risk assessment. Available at: https://apps.who.int/iris/handle/10665/69477. Accessed Mar 15, 2022.
17. Soleimani Z, Boloorani AD, Khalifeh R, Teymouri P, Mesdaghinia A, Griffin DW. Air pollution and respiratory hospital admissions in Shiraz, Iran, 2009 to 2015. Atmosph Environ 2019;209:233–9.
18. Xie J, Teng J, Fan Y, Xie R, Shen A. The short-term effects of air pollutants on hospitalizations for respiratory disease in Hefei, China. Int J Biometeorol 2019;63:315–26.
19. Wang S, Li Y, Niu A, Liu Y, Su L, Song W, et al. The impact of outdoor air pollutants on outpatient visits for respiratory diseases during 2012-2016 in Jinan, China. Respir Res 2018;19:246.
20. Szyszkowicz M, Kousha T, Castner J, Dales R. Air pollution and emergency department visits for respiratory diseases: A multi-city case crossover study. Environ Res 2018;163:263–9.
21. Türkiye Cumhuriyeti Sağlık Bakanlığı. 2018. T.C.Sağlık Bakanlığı Sağlık İstatistikleri Yıllığı. Available at: https://ohsad.org/wp-content/uploads/2020/01/SB_istatistik-y%C4%B1l-l%C4%B1%C4%9F%C4%B1-2018.pdf. Accessed Mar 15, 2022.
22. Yalnız E, Uslu Ö, Bolat E, Altın S, Polat G. Does the hospital admission of patients with respiratory disease increase in Izmir when the PM_{10} level is high? Turk Thorac J 2020;21:32–8.
23. Mercan Y, Babaoglu UT, Erturk A. Short-term effect of particular matter and sulfur dioxide exposure on asthma and/or chronic obstructive pulmonary disease hospital admissions in Center of Anatolia. Environ Monit Assess 2020;192:646.
24. Unver E, Bolat E, Altin S, Coban A, Aktas M, Ficici M, et al. The effect of air pollution on respiratory system disease admissions and health expenditures. Eur J Med Investigation 2019;3:137–43.
25. Tasci SS, Kavalci C, Kayipmaz AE. Relationship of meteorological and air pollution parameters with pneumonia in elderly patients. Emerg Med Int 2018;2018:4183203.
26. Saygın M, Gonca T, Öztürk Ö, Has M, Çalışkan S, Has ZG, et al. To investigate the effects of air pollution (PM_{10} and SO_2) on the respiratory diseases asthma and chronic obstructive pulmonary disease. Turk Thorac J 2017;18:33–9.
27. Berktaş BM, Bircan A. Effects of atmospheric sulphur dioxide and particulate matter concentrations on emergency room admissions due to asthma in Ankara. Tuberk Toraks 2003;51:231–8.
28. Kulinska E, Dendera-Gruszka M. Green cities – problems and solutions in Turkey. Transp Res Procedia 2019;39:242–51.
29. Baris ME, Erdogan E, Dilaver Z, Arslan M. Greenways and the urban form: City of Ankara, Turkey. Biotechnol Biotechnol Equip 2010;24:1657–64.
30. Project Coordination Department of OSTIM Industrial Investment and Business Inc. June 2013. Power of SMEs in development & OSTIM experience. Available at: https://www.ostimyatirim.com.tr/content/upload/attached-files/ostimindustrialcitymod-25-20201126222739.pdf. Accessed Mar 15, 2022.
31. Turkish Ministry of Environment and Urbanization. National Air Quality Monitorization Network. Available at: https://sim.csb.gov.tr/STN/STN_Report/StationDataDownloadNew. Accessed Mar 15, 2022.
32. Turkish Ministry of Environment and Urbanization. National Air Quality Monitorization Network. Available at: https://sim.csb.gov.tr/Home/HKI?baslik=HAVZA%20%C4%B0ZLEME%20S%C4%B0STEM%C4%B0. Accessed Mar 15, 2022.
33. Li R, Jiang N, Liu Q, Huang J, Guo X, Liu F, et al. Impact of air pollutants on outpatient visits for acute respiratory outcomes. Int J Environ Res Public Health 2017;14:47.
34. Yee J, Cho YA, Yoo HJ, Yun H, Gwak HS. Short-term exposure to air pollution and hospital admission for pneumonia: A systematic review and meta-analysis. Environ Health 2021;20:6.
35. Raji H, Riahi A, Borsi SH, Masoumi K, Khanjani N, AhmadiAngali K, et al. Acute effects of air pollution on hospital admissions for asthma, COPD, and bronchiectasis in Ahvaz, Iran. Int J Chron Obstruct Pulmon Dis 2020;15:501–14.
36. Zhu M, Peng H, Wan L, Zhang S, Zeng Y. The role of elevated red blood cell distribution width in the prognosis of AECOPD patients: A retrospective study. Medicine (Baltimore) 2021;100:e25010.
37. Gong C, Yang Y, Chen M, Xie Z. Effect of procalcitonin on the prognosis of patients with COPD. Biomed Rep 2020;12:313–8.
38. Pizzini A, Lunger F, Sahanic A, Nemati N, Fuchs D, Weiss G, et al. Diagnostic and prognostic value of inflammatory parameters including neopterin in the setting of pneumonia, COPD, and acute exacerbations. COPD 2017;14:298–303.
39. Yadav R, Nagori A, Mukherjee A, Singh V, Lodha R, Kabra SK, et al. Effects of ambient air pollution on emergency room visits of children for acute respiratory symptoms. MedRxiv 2020.11.17.20223701.
40. Hamatui N, Beynon C. Particulate matter and respiratory symptoms among adults living in Windhoek, Namibia: A cross sectional descriptive study. Int J Environ Res Public Health 2017;14:110.
41. Cengiz MA, Senel T, Terzi E, Savas N, Terzi Y. Samsun bölgesindeki hava kirliliğinin neden olduğu hastalıkların istatistiksel modellenmesi. The Black Sea J Sci 2013;3:27–36.