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Original Article

Emergency Admissions Due to Respiratory Problems in Children Change with Extend of Air Pollution

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ABSTRACT

Aim: Outdoor air pollution can cause many acute or chronic diseases in childhood, with respiratory tract diseases being the leading outcome. Very little childhood data exists to investigate the levels of exposure to pollution. This study aimed to reveal the relationship between pollution and acute respiratory disease in children.

Materials and Methods: This study involved 38,696 patients admitted to pediatric emergency services with respiratory complaints. PM_{10} and SO_2 were selected as indicators of air pollution. Daily data on these indicators were obtained from the province's Air Quality Monitoring Stations website. Data were assessed using descriptive statistics, Pearson's correlation test, and logistic regression.

Results: Among the admitted children, 44.8% were female, and 55.2% were male, with the majority (42.3%) aged 0-3 years. PM_{10} levels exceeded the World Health Organization daily limit (50 μg/m³) on 314 days, with a mean value of 76.54±28.13 μg/m³. SO_2 levels exceeded the 20 μg/m³ limit on 17 days, with a mean of 9.99±5.79 μg/m³. Positive correlations were found between PM_{10} and SO_2 with respect to hospital admissions ($p<0.01$). Logistic regression revealed significant associations between PM_{10} and all respiratory conditions, while SO_2 was linked to acute nasopharyngitis, upper respiratory infections, bronchiolitis, and asthma ($p<0.01$).

Conclusion: Parameters regarding outdoor air pollution positively correlated with acute respiratory tract findings in childhood and acute exacerbation of chronic diseases. Therefore, outdoor air pollution should be considered the most important environmental risk factor for childhood respiratory tract health.

Keywords: Air pollution, respiratory tract diseases, PM_{10}, SO_2

Introduction

Air pollution is a significant public health hazard, especially in urban areas (1,2). Current scientific evidence suggests a potential relationship between urban air pollution and adverse health effects, especially on the respiratory system (3,4). Children are among the most vulnerable populations (5,6).

Some pollutants found in the air are emitted directly from a source. These are called primary pollutants. The other pollutants, known as secondary pollutants, are formed when primary pollutants react in the atmosphere with other pollutants. In urban regions, the most important secondary pollutant is ozone (O_3), formed due to an atmospheric reaction between nitrogen oxides (NOx), and

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volatile organic compounds in the presence of sunlight. When considered from this point of view, the "critical air pollutants" are O_3, carbon monoxide (CO), NOx, sulfur dioxide (SO_2), lead (Pb), and particulate matter (PM) (7). Solid (dust, ash, Pb) or liquid (haze, smoke, oil, acids, etc.) particles which are larger than gas molecule sizes (0.0002-0.0003 gm) and suspended in the air for a while are classified as PM. PM_{10} (PM with an aerodynamic diameter of 10 micrometers or less) is a major air pollutant composed of suspended solid or liquid particles. Due to their respirable nature, they can penetrate deep into the lower respiratory tract, potentially causing adverse health effects (8). The potential of PM to cause health problems is strongly influenced by its size, as smaller particles can penetrate deeper into the respiratory tract and reach the alveolar regions.

Many studies have revealed that children are more susceptible to air pollution's acute and chronic effects (9-12). For children, the primary air pollutants are PM_{10}, NOx, SOx, CO, and O_3 (13). Despite air pollution and increasing concern about the number of respiratory tract infection cases, especially in metropolitan areas, research on the effects of pollutants on the upper respiratory tract is relatively limited. Epidemiological studies on children and adolescents have shown the impact of pollutants in general without assessing the actual effects on different age groups (14-16). This study aimed to analyze the relationship between the main parameters of air pollution in the city center of Manisa and acute respiratory diseases, which are one of the reasons for the emergency admission of children living in this region.

Materials and Methods

Study Population

The study was conducted with 38,696 patients in total, 8,840 of whom were admitted to the Pediatric Emergency Department of Manisa Celal Bayar University Hospital (CBUH) with respiratory complaints and 29,856 of whom were admitted to the Pediatric Emergency Department of Manisa Merkez Efendi Hospital (MMEH) between the dates of January 1st, 2017 and December 31st, 2017. This research was approved by the Celal Bayar University Hospital Ethics Committee (approval no.: 20.478.486, dated; 14.03.2018). All procedures were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. The families of all patients were informed about the objectives of this study and the potential publication of medical data, and written informed consent was obtained from the patients' parents.

Patients diagnosed with one of the acute respiratory tract diseases aged between 0-17 years were included in this study. Patients with International Statistical Classification of Diseases and Related Health Problems diagnosis codes J00, J45, J06, H66, J20, and J21 were screened. Acute respiratory tract diseases were classified as acute nasopharyngitis, asthma, acute upper respiratory tract infection, otitis media, acute bronchitis, or acute bronchiolitis. The first admission of those patients admitted more than once were included in this study. Those cases with chronic systemic disease of another system, those patients with incomplete data, re-admissions, or underlying chronic conditions were excluded.

Study Design and Data Collection

This study was planned as a cross-sectional research. Information on age, gender, date of admission, and diagnosis of the cases were obtained from the patient files. Any further data not included in the patient files were obtained via phone call. The first admission of those patients admitted more than once were included in this study.

Atmospheric Air Pollution Parameters

The data on air pollution in the city center of Manisa were obtained from the Website of Air Quality Monitoring Stations operated by the Ministry of Environment and Urbanization. According to the air pollution data of Manisa city center, the pollutants measured at the air quality monitoring station were PM_{10} and SO_2, and daily average values were determined in order to estimate the air pollution value for each admission with regard to these pollutants.

Statistical Analysis

Analysis was performed using Statistical Package for the Social Sciences for Windows, version 25.0 (IBM Inc., Armonk, NY, USA). Descriptive statistics are reported as mean ± standard deviation for normally distributed variables and median (range) for skewed data. The data were analyzed using descriptive statistics (frequency, percentage distribution, mean, and standard deviation), Pearson's correlation test, and logistic regression analysis.

Results

Of the children who applied to the pediatric emergency clinic with respiratory complaints, 44.8% were girls, and 55.2% were boys. 42.3% of the cases were between the ages of 0-3, 23.4% were between the ages of 4-6, 26% were between the ages of 7-12, and 8.3% were between the ages of 13-17. Of the cases, there were some smokers in the 13-17 age group, and their ratio to all patients was 1%. While

the most frequent diagnosis in girls was bronchitis, it was upper respiratory tract infection in boys. The most frequent age range at diagnosis was 0-3, both in girls and boys. Similarly, the most frequent age range at diagnosis for all the patients was 0-3. Diagnoses by gender and age groups are summarized in Table I.

When analyzing the distribution of diagnoses by months, it was detected that acute nasopharyngitis and acute upper respiratory tract infection were most frequently seen in October, acute bronchitis and acute bronchiolitis were most frequently seen in February, otitis media was most frequently seen in March, and asthma was most frequently seen in May (Table II).

During the study period, the level of PM_{10} measured at the station was above the limit value, which was set at daily 50 μg/m³ by World Health Organization (WHO), for 314 days out of the 365 days, and the measured mean PM_{10} value was 76.54±28.13 μg/m³. It is seen in the monthly assessments that the PM_{10} value reached its highest level in November with 118.80±6.55 μg/m³. During the same period, the daily SO_2 limit, which was set as 20 μg/m³ by WHO, was exceeded at the station for 17 days out of the 365 days, and the mean SO_2 value was 9.99±5.79 μg/m³. It can be seen in the monthly assessments that the SO_2 value reached its highest level in November at 16.00±1.14 μg/m³. The mean PM_{10} and SO_2 values by month are given in Table III.

When the number of patients admitted to pediatric emergency services was assessed month by month, it was detected that the maximum number of admissions to CBUH was in January with 1,166 children, and the maximum admission to MMEH was in October with 3,332 children. When considering the total number of admissions, October had the highest admission rate with 4,144 children.

Significant results were achieved in the correlation analysis conducted to assess the relationship between PM_{10} and SO_2 concentrations and the number of hospital admissions to pediatric emergency departments. Accordingly, there were significant positive correlations between [PM_{10} and CBUH admissions ($r=0.280$, $p<0.01$), PM_{10} and MMEH admissions ($r=0.404$, $p<0.01$), PM_{10} and total admissions ($r=0.407$, $p<0.01$)]. Similarly, significant positive correlations existed between SO_2 and CBUH, MMEH, and the total number of admissions (SO_2 and CBUH admissions ($r=0.379$, $p<0.01$), SO_2 and MMEH admissions ($r=0.467$, $p<0.01$), SO_2 and total admissions ($r=0.407$, $p<0.01$)]. These correlation results are summarized in Table IV.

In the logistic regression analysis conducted to observe the effects of PM_{10} and SO_2 on diagnoses relating to the respiratory system, it was detected that PM_{10} and SO_2 affected diagnosis. Accordingly, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis, acute bronchiolitis, otitis media, and asthma increased as

Table I. Diagnoses by gender and age groups

Age groups		Diagnosis						Total
		Acute nasopharyngitis	Acute upper respiratory tract infection	Acute bronchitis	Acute bronchiolitis	Otitis media	Asthma	
Girl	0-3	1,042	3,277	1,324	466	1,034	29	7,172
	4-6	572	1,868	770	246	604	22	4,082
	7-12	654	2,095	841	291	655	25	4,561
	13-17	227	674	282	99	209	15	1506
	All ages	2,495	7,914	3217	1102	2,502	91	17,321
Boy	0-3	1,326	4,197	1,703	572	1,349	47	9,194
	4-6	740	2,261	907	326	705	30	4,969
	7-12	799	2,499	1,030	355	792	27	5,502
	13-17	234	798	315	105	254	4	1,710
	All ages	3,099	9,755	3,955	1,358	3,100	108	21,375
All patients	0-3	2,368	7,474	3,027	1,038	2,383	76	16,366
	4-6	1,312	4,129	1,677	572	1,309	52	9,051
	7-12	1,453	4,594	1,871	646	1,447	52	10,063
	13-17	461	1,472	597	204	463	19	3,216
	All ages	5,594	17,669	7,172	2,460	5,602	199	38,696

Table II. Seasonal diagnosis percentages

Season	Acute nasopharyngitis	Acute upper respiratory tract infection	Acute bronchitis	Acute bronchiolitis	Otitis media	Asthma
Fall	17.8%	49.8%	16.5%	4.5%	10.7%	0.4%
Winter	13.6%	40.8%	22%	7.6%	15.2%	0.49%
Spring	12%	41%	20.4%	7.8%	17.8%	0.69%
Summer	13.4%	53.4%	13%	5%	14.5%	0.34%

Table III. Mean PM_{10} and SO_2 values by month

Month	PM_{10} (µg/m³)	SO_2 (µg/m³)
January	78.46±6.24	8.46±0.90
February	74.50±5.80	7.18±0.60
March	84.23±3.51	10.10±0.86
April	72.17±3.28	9.57±0.79
May	71.48±3.98	7.03±0.64
June	62.33±3.79	7.62±0.57
July	60.68±1.52	8.42±0.63
August	63.97±1.14	7.48±0.53
September	71.10±2.82	11.62±0.81
October	69.81±2.64	10.03±0.88
November	118.40±6.55	16.00±1.14
December	99.14±9.30	15.58±1.14

PM_{10}: Particulate matter having particle size 10 micrometers or less in diameter, SO_2: Sulfur dioxide, Unit: µg/m³

Table IV. The relationship between PM_{10}-SO_2 and the number of admissions to the pediatric emergency department

	PM_{10}	SO_2	CBUH	MMEH	Total
PM_{10}	1	0.853**	0.280**	0.404**	0.407**
SO_2		1	0.140**	0.467**	0.379**
CBUH			1	0.558*	0.760**
MMEH				1	0.963**
Total					1

*p<0.05 and **p<0.01
PM_{10}: Particulate matter having particle size 10 micrometers or less in diameter, SO_2: Sulfur dioxide, CBUH: Celal Bayar University Hafsa Sultan Hospital, MMEH: Manisa Merkez Efendi Hospital

PM_{10} levels increased. Additionally, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchiolitis, and asthma increased in line with increases in SO_2. The odds ratio (OR), confidence interval (CI), and p-values are given in Table V. The highest effect of PM_{10} [OR; 95% CI 0.131 (1.19-1.44); p<0.01], and SO_2 [OR; 95% CI 1.27 (1.12-1.42); p<0.01] on diagnoses was for the diagnosis of acute upper respiratory tract infection.

Table V. The effect of PM_{10} and SO_2 on diagnosis relating respiratory system

	PM_{10} OR (95% CI)	SO_2 OR (95% CI)
Acute nasopharyngitis	1.16 (1.06-1.26)**	1.19 (1.09-1.30)**
Acute upper respiratory tract infection	1.31 (1.19-1.44)**	1.27 (1.12-1.42)**
Acute bronchitis	1.14 (1.02-1.28)*	1.20 (1.06-1.31)
Acute bronchiolitis,	1.17 (1.03-1.33)*	1.14 (0.99-1.29)**
Otitis media	1.03 (0.88-1.16)*	0.97 (0.81-1.08)
Asthma	1.18 (1.07-1.3)**	1.24 (1.14-1.34)*

**p<0.01 and *p<0.05 Pearson's correlation test. unit: µg/m³
PM_{10}: Particulate matter having particle size 10 micrometers or less in diameter, SO_2: Sulfur dioxide, OR: Odds ratio, CI: Confidence interval

Discussion

In the present study, we investigated the relationships between pediatric respiratory conditions, air pollution, and seasonal variations. Our results demonstrated a significant correlation between the number of patients admitted to the pediatric emergency department with respiratory complaints and PM_{10} and SO_2 levels, which were considered as being the key air pollutants in this research. The number of admissions was also at its highest level in line with the highest levels of air pollution, especially in November and December. Also, it was revealed that air pollution significantly affected all respiratory system diseases. This study was conducted based on establishing a link between air pollution and seasonal factors with the prevalence of respiratory illnesses in pediatric populations. Hence, strengthening preventive health services in areas with intense air pollution may reduce the frequency of respiratory diseases in the pediatric population.

Among the pediatric cases evaluated, the distribution of respiratory complaints demonstrates significant age and gender variations. Boys constituted 55.2% of the cases, while girls accounted for 44.8%. The majority of cases (42.3%) were in the 0-3 age group, emphasizing the vulnerability of younger children to respiratory illnesses. This aligns

with previous research, which has established that younger children are at a higher risk of respiratory diseases due to their immature immune systems and narrower airways (17).

Seasonal analysis revealed distinct patterns in the occurrence of respiratory illnesses. Acute nasopharyngitis and acute upper respiratory tract infections were most prevalent in October, corresponding to the fall months, whereas acute bronchitis and bronchiolitis peaked in February during the winter. Otitis media was most frequently diagnosed in March, and asthma exacerbations were highest in May. These findings are consistent with seasonal fluctuations in respiratory virus activity and allergen levels, as well as variations in ambient air pollution during the colder months (18,19).

In many studies, PM_{10} and SO_2 are considered significant and frequently analyzed pollutants for assessing health risks caused by air pollution (20-22). They are also frequently used indicators in studies evaluating the relationship between air pollution and respiratory system diseases (2). Based on previous research, PM_{10} and SO_2 were also selected as air-pollution indicators in this study. Our results showed that air pollution, measured in terms of PM_{10} and SO_2 concentrations, had a significant impact on pediatric respiratory health. This study reported a mean PM_{10} value of 76.54 μg/m³, exceeding the WHO daily limit of 50 μg/m³ on 314 days of the year. Similarly, SO_2 concentrations surpassed the WHO daily limit on 17 days. High PM_{10} levels were observed in November, while SO_2 peaked during the same month. These results align with earlier studies which demonstrated that increased air pollution levels correlate with higher rates of pediatric emergency admissions for respiratory conditions (23,24). The positive correlations between PM_{10}, SO_2, and hospital admissions emphasize the critical role of air quality in exacerbating respiratory conditions, particularly in vulnerable populations. Similarly, it was detected in the research conducted by Farhat et al. (25) between August 1996 and August 1997 on 43,635 children admitted to the respiratory emergency department of Sao Paulo University Hospital that there were significant correlations between the number of admissions and the levels of PM_{10}, SO_2, NO_2, and CO.

In the scope of our research, it was revealed via logistical regression analysis conducted to observe the effects of PM_{10} and SO_2 on diagnoses relating to the respiratory system that PM_{10} and SO_2 affected these diagnoses. Accordingly, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis, acute bronchiolitis, otitis media, and asthma increased as PM_{10} levels increased. Additionally, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchiolitis, and asthma increased in line with increasing levels of SO_2. PM_{10} and SO_2 had the most significant effect on acute upper respiratory tract infection diagnoses. In another study by Sunyer et al. (26), it was shown that emergency department visits due to adult chronic obstructive pulmonary disease were correlated with air pollution. An analysis of adults and children in London revealed that PM_{10} and SO_2 had significant effects on asthma and other lower respiratory tract diseases (27). These findings underscore the need for stringent air quality regulations and public health interventions in order to mitigate the adverse effects of air pollution on children's respiratory health (28,29).

Study Limitations

This study has several limitations. Firstly, its retrospective design limits the ability to establish a direct causal relationship between air pollution and pediatric respiratory diseases. Secondly, other environmental and socioeconomic factors, such as indoor air pollution, household smoking, and pre-existing medical conditions, were not accounted for, potentially affecting the observed associations. Furthermore, this study only focused on PM_{10} and SO_2 as primary pollutants, while other air pollutants, such as NO_2 and O_3, which may also contribute to respiratory illnesses, were not included in the analysis. Future research incorporating more comprehensive air quality monitoring and individual-level exposure assessments is needed in order to further elucidate these associations.

Conclusion

It was observed that there was a significant correlation between the number of patients admitted to the pediatric emergency department with respiratory complaints and PM_{10} and SO_2 levels, which were considered as the main air pollutants in this research. The number of admissions was also at its highest level in line with the highest levels of air pollution, especially in November and December. Also, it was revealed that air pollution had significant effects on all respiratory system diseases. Even if it is hard to isolate the effect of PM_{10} and SO_2, as many air pollutants cause respiratory complaints, our findings showed that air pollution is a significant public health problem in Manisa. This study provides compelling evidence linking air pollution and seasonal factors to the prevalence of respiratory illnesses in pediatric populations. Effective public health measures, including air quality control, vaccination programs, and increased awareness among parents and caregivers are essential in order to reduce the incidence

and severity of these conditions. This study also highlights a critical link between air pollution, seasonal variation, and the healthcare burden. It underscores the importance of implementing real-time air quality monitoring and public advisories during periods of high pollution in order to reduce the burden on the healthcare system.

Ethics

Ethics Committee Approval: The research was approved by the Manisa Celal Bayar University Hospital Ethics Committee (approval no.: 20.478.486, dated; 14.03.2018).

Informed Consent: The families of all patients were informed about the objectives of the study and the potential publication of medical data, and written informed consent was obtained from the patients' parents.

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Footnotes

Authorship Contributions

Concept: B.K., Design: B.K., H.Y., Data Collection or Processing: Ö.Y., Analysis or Interpretation: Ö.Y., Literature Search: H.Y., Writing: B.K., Ö.Y.

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

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References

1. Venn AJ, Lewis SA, Cooper M, Hubbard R, Britton J. Living near a main road and the risk of wheezing illness in children. Am J Respir Crit Care Med. 2001; 164:2177-80.
2. Grigg J. Air pollution and children's respiratory health-gaps in the global evidence. Clin Exp Allergy. 2011; 41:1072-5.
3. Schwartz J. Air pollution and children's health. Pediatrics. 2004; 113(4 Suppl):1037-43.
4. Trasande L, Thurston GD. The role of air pollution in asthma and other pediatric morbidities. J Allergy Clin Immunol. 2005; 115:689-99.
5. Moya J, Bearer CF, Etzel RA. Children's behavior and physiology and how it affects exposure to environmental contaminants. Pediatrics. 2004; 113(4 Suppl):996-1006.
6. Goldman L, Falk H, Landrigan PJ, Balk SJ, Reigart JR, Etzel RA. Environmental pediatrics and its impact on government health policy. Pediatrics. 2004; 113(4 Suppl):1146-57.
7. U.S. EPA. Report on the 2013 U.S. Environmental Protection Agency (EPA) International Decontamination Research and Development Conference . Research Triangle Park, NC, November 05 - 07, 2013. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/210, 2014.
8. Mukherjee A, Agrawal M. World air particulate matter: sources, distribution and health effects. Environ Chem Lett. 2017; 15:283-309.
9. Munoz-Pizza DM, Villada-Canela M, Reyna MA, Texcalac-Sangrador JL, Osornio-Vargas ÁR. Air pollution and children's respiratory health: a scoping review of socioeconomic status as an effect modifier. Int J Public Health. 2020; 65:649-60.
10. Garcia E, Rice MB, Gold DR. Air pollution and lung function in children. J Allergy Clin Immunol. 2021; 148:1-14.
11. Bobrowska-Korzeniowska M, Jerzyńska J, Polańska K, Kaleta D, Stelmach I, Kunert A, et al. The effect of air pollution on the respiratory system in preschool children with contribution of urban heat islands and geographic data - the aim of the study and methodological assumptions. Int J Occup Med Environ Health. 2021; 34:453-60.
12. Carraro S, Ferraro VA, Zanconato S. Impact of air pollution exposure on lung function and exhaled breath biomarkers in children and adolescents. J Breath Res. 2022; 16.
13. Leikauf GD, Kline S, Albert RE, et al. Evaluation of a possible association of urban air toxics and asthma. Environ Health Perspect. 1995; 103(Suppl 6):253-71.
14. Peel JL, Tolbert PE, Klein M, et al. Ambient air pollution and respiratory emergency department visits. Epidemiology. 2005; 16:164-74.
15. Wong TW, Tam W, Tak Sun Yu I, Wun YT, Wong AH, Wong CM. Association between air pollution and general practitioner visits for respiratory diseases in Hong Kong. Thorax. 2006; 61:585-91.
16. Larrieu S, Lefranc A, Gault G, et al. Are the short-term effects of air pollution restricted to cardiorespiratory diseases? Am J Epidemiol. 2009; 169:1201-8.
17. Hasegawa K, Brown DF, Tsugawa Y, Camargo CA Jr. Epidemiology of emergency department visits for opioid overdose: a population-based study. Mayo Clin Proc. 2014; 89:462-71.
18. Fann N, Lamson AD, Anenberg SC, Wesson K, Risley D, Hubbell BJ. Estimating the national public health burden associated with exposure to ambient PM2.5 and ozone. Risk Anal. 2012; 32:81-95.
19. Al-Tawfiq JA, Kattan RF, Memish ZA. Epidemiology and seasonal pattern of respiratory tract infections among children in a hospital in Saudi Arabia. Eur J Hosp Med. 2023; 91:87-92.
20. Li S, Wu W, Wang G, et al. Association between exposure to air pollution and risk of allergic rhinitis: a systematic review and meta-analysis. Environ Res. 2022; 205:112472.
21. Tamehri Zadeh SS, Khajavi A, Ramezankhani A, Azizi F, Hadaegh F. The impact of long-term exposure to PM10, SO2, O3, NO2, and CO on incident dysglycemia: a population-based cohort study. Environ Sci Pollut Res Int. 2023; 30:3213-21.
22. Meo SA, Salih MA, Al-Hussain F, Alkhalifah JM, Meo AS, Akram A. Environmental pollutants PM2.5, PM10, carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3) impair human cognitive functions. Eur Rev Med Pharmacol Sci. 2024; 28:789-96.
23. Zhang Y, Qian Z, Chang J, et al. Ambient air pollution and children's respiratory health in urban and suburban areas of China. Environ Pollut. 2009; 231(Pt 1):546-52.

24. Pope CA 3rd, Ezzati M, Dockery DW. Fine-particulate air pollution and life expectancy in the United States. N Engl J Med. 2009; 360:376-86.

25. Farhat SC, Paulo RL, Shimoda TM, et al. Effect of air pollution on pediatric respiratory emergency room visits and hospital admissions. Braz J Med Biol Res. 2005; 38:227-35.

26. Sunyer J, Antó JM, Murillo C, Saez M. Effects of urban air pollution on emergency room admissions for chronic obstructive pulmonary disease. Am J Epidemiol. 1991; 134:277-86; discussion 287-9.

27. Hajat S, Haines A, Goubet SA, Atkinson RW, Anderson HR. Association of air pollution with daily GP consultations for asthma and other lower respiratory conditions in London. Thorax. 1999; 54:597-605.

28. Schraufnagel DE, Balmes JR, Cowl CT, et al. Air pollution and non-communicable diseases: a review by the Forum of International Respiratory Societies' environmental committee, part 2: air pollution and organ systems. Chest. 2019; 155:417-26.

29. Orellano P, Kasdagli MI, Pérez Velasco R, Samoli E. Long-term exposure to particulate matter and mortality: an update of the WHO Global Air Quality Guidelines systematic review and meta-analysis. Int J Public Health. 2024; 69:1607683.