Air pollution and its effects on emergency room visits in tertiary respiratory care centers in Delhi, India

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Abstract

Environmental pollution has harmful effects on human health, particularly the respiratory system. We aimed to study the impact of daily ambient air pollution on daily emergency room visits for acute respiratory symptoms. This study was conducted at two tertiary respiratory care centers in Delhi, India. Daily counts of emergency room visits were collected. All patients attending the emergency room were screened for acute onset (less than 2 weeks) of respiratory symptoms and were recruited if they were staying in Delhi continuously for at least 4 weeks and had onset (≤2 weeks) of respiratory symptoms. Daily average air pollution data for the study period was obtained from four continuous ambient air quality monitoring stations. A total of 61,285 patients were screened, and 11,424 were enrolled from June 2017 to February 2019. Coughing and breathing difficulty were the most common respiratory symptoms. Poor air quality was observed from October to December. Emergency room visits with acute respiratory symptoms significantly increased per standard deviation increase in particulate matter 10 from lag days 2-7. An increase in wheezing was primarily seen with an increase in nitrogen dioxide. Pollutant levels have an effect on acute respiratory symptoms and thus influence emergency room visits.

Introduction

Air pollution has been known to cause detrimental effects not only on the climate but also on human health [1]. It adversely affects cardiovascular and respiratory health, with both short-term and long-term consequences. Short-term exposure to pollutants has been linked to chronic obstructive pulmonary disease (COPD), asthma, and other respiratory diseases. Also, high rates of hospitalization, which is a measure of morbidity, have been found to be related to air pollution. On the other hand, long-term effects like chronic asthma, pulmonary insufficiency, and cardiovascular diseases have been found to be associated with air pollution [2,3].

Particulate matter (PM), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) are major outdoor air pollutants [4]. The detrimental effects of air pollution on respiratory health include a decline in lung functions, an increase in respiratory infections, the exacerbation of chronic respiratory diseases, and increased respiratory morbidity and mortality [4-9]. Various studies have shown the short-term effects of air pollutants on respiratory mortality and morbidity in terms of increased emergency room visits (ERV) [5,6,10-14].

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However, studies from the Indian subcontinent in this context are limited. Some studies have reported an increase in all-cause mortality [15-17]. One study from Chennai showed an increase in daily all-cause mortality per 10-pg/m^3 increase in daily average PM10 concentrations [15], while others from Delhi showed increased all-natural-cause mortality with a rise in PM10, PM2.5 exposure, and gaseous pollutants [16-18]. A few studies have reported the association between hospital admissions, outpatient visits, and air pollution [18-22]. Even fewer studies have evaluated the relationship between respiratory morbidity (in terms of ERV) and air pollution [23,24]. Therefore, we planned to study the impact of daily ambient air pollution on daily ERV for acute respiratory symptoms in Delhi in two tertiary respiratory care centers. We also looked at the individual impact of pollutants after adjusting for weather and holidays.

Materials and Methods

This study was carried out in Delhi from June 2017 to February 2019. This study was part of a multi-site task force project supported by the Indian Council of Medical Research. Two of the tertiary respiratory care hospitals in Delhi were selected. Vallabhbhai Patel Chest Institute (VPCI) and the National Institute of Tuberculosis and Respiratory Diseases (NITRD), both of which cater to a substantial number of patients suffering from chest diseases. Daily counts of ERV to hospitals were collected from these two hospitals in Delhi. All patients attending the emergency room were screened for acute onset (less than 2 weeks) of respiratory symptoms by personal interview and enrolled in the study. The diagnosis was also recorded from the patient's card. Patients were recruited if they were staying in Delhi continuously for at least 4 weeks and had onset (≤2 weeks) of respiratory symptoms, as well as those with exacerbations of chronic lung disease in the last 2 weeks. After obtaining written informed consent from the eligible patients, the demographics, diagnosis, and clinical details were recorded from the patient card in the study proforma. Data was collected through a personal interview for demographics (age, gender, residential address), clinical details (diagnosis from the patient card, details of respiratory symptoms, outcomes at 12 hours), and factors related to indoor air pollution (cooking fuel and smoking at home).

Daily average air pollution data for the study period was obtained from four continuous ambient air quality monitoring stations located in Anand Vihar, Mandir Marg, R.K. Puram, and Punjabi Bagh. Daily 24-h average concentrations of six pollutants, namely PM10, PM2.5, NO_2, SO_2, and CO, three 8-h concentrations of O_3, daily mean temperature, and relative humidity data were collected from the Delhi Pollution Control Committee.

Statistical analysis

Time-series analysis was done to explore the delayed association between outcomes considering exposure to air pollutants in the previous 1-7 days. Similarly, the association between the ambient air pollutants and the percentage of total daily enrolled patients with individual respiratory symptoms (cough, difficulty in breathing, and nasal symptoms) on the same days as well as up to the previous 1-7 days of exposure to pollutants was assessed.

To assess the association between the ambient air pollutant concentrations and the daily acute respiratory ERV of adults, a generalized-additive model with the Poisson link function was used after adjusting for day of the week (DOW), national holidays, season, temperature, and relative humidity. Models were fitted using the following equation (Eq. 1):

$$\text{Log}(E(Y0))=\text{Intercept}+\beta 1(P1_{0\text{-}L})+\beta 2(P2_{0\text{-}L})+\ldots\ldots\ldots+\beta x(Px_{0\text{-}L})+s(\text{Temperature}_{0\text{-}L},df=3)+s(\text{Relative humidity}_{0\text{-}L},\ df=3)+s(\text{Time of year},\ df=3)+\beta d(\text{DOW})+\beta h(\text{Holiday}) \quad \text{(Eq. 1)}$$

Where E(Y0) is the expected percentage of daily patient ERV for acute respiratory symptoms on day 0(day of visit); β is the regression coefficient for different pollutants; $P1_{0\text{-}L}$, $P2_{0\text{-}L}$, $Px_{0\text{-}L}$ are the moving average concentrations of air pollutants for 0-Lag days; and s represents the smoother based on the penalized smoothing spline for variables, temperature, relative humidity, and time of the year. DOW represents weekdays or weekends; Holiday represents national holidays. βd is the coefficient for DOW, βh is the coefficient for the holiday.

The lag effect of each pollutant was assessed on moving average lag structures (0-1, 0-2, 0-3, 0-4….0-7). The minimum Akaike information criterion (AIC) models were selected for selecting the best lag structure for every pollutant. Multi-pollutant models were fitted on the moving average lag structures (0-1, 0-2, 0-3, 0-4….0-7) with all six pollutants for every symptom. The final lag structure was selected using the backward elimination method, using minimum AIC criteria values for making the final model. Sensitivity analysis was performed for varying degrees of freedom (df=3 to df=6) at the selected lag structure for the time of year and moving average of temperature and humidity.

All analyses were carried out using R, version V.3.6 (R Foundation for Statistical Computing, Vienna, Austria). Effect estimates were presented as percentage changes and 95% confidence intervals in daily hospital admissions in relation to per 1 standard deviation (SD) increase in moving of 0-7 lag day's concentrations.

Results

A total of 61,285 patients were screened in the emergency from June 1st, 2017 to February 28th, 2019. Figure 1 shows the screening and enrolment of patients from NITRD and VPCI. The demographic and clinical characteristics of the patients are shown in Table 1. Coughing and difficulty in breathing were the most common respiratory symptoms. Most of the patients were managed with ambulatory treatment, with only a small percentage requiring admission. A major percentage of patients reporting to the emergency were followed up with diagnosed cases of post-tubercular sequelae, asthma, and COPD.

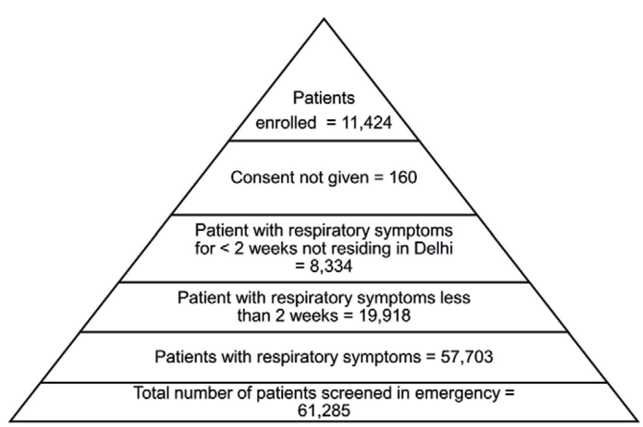

Figure 1. Screening and enrolment of patients from the National Institute of Tuberculosis and Respiratory Diseases and the Vallabhbhai Patel Chest Institute.

The levels of six air pollutants were variable during the 21-month study period from June 2017 to February 2019. Poor air quality was observed from October to December and also in June 2018, which could be attributed to a heavy dust storm. From March to June, low peaks of air pollutants were recorded, showing moderate air quality. The air quality was satisfactory in the monsoon season from July to September (Figure 2). ERV with acute respiratory symptoms (≤2 weeks) significantly increased per SD increase in PM10 and NO_2 from lag days 2-7 and lag days 1-2, respectively. A significant decrease was seen in the ERV with an increase in PM2.5 and SO_2 from lag days 1-7 (Table 2). There was an increase in patients presenting with cough on lag days 5-7,4-7 and 2-4,6 for O_3, PM10, and PM2.5, respectively. However, a decrease was observed with CO, SO_2, and NO_2 except for NO_2 on lag day one. An increase in wheezing was primarily seen with an increase in NO_2 on lag days 1-7. There was a significant increase in patients presenting with difficulty in breathing with an increase in the concentration of NO_2, O_3, and PM2.5 on lag days 1-2, 3, and 6, respectively. Patients presenting to an emergency with nasal symptoms increased per SD increase in NO_2 and PM10 from lag days 1-7 and 6-7. Figure 3 shows the change in ERV and symptoms, that is, cough, nasal symptoms, wheezing, and difficulty in breathing per SD change, which increases pollutant levels.

Discussion

Air pollution is known to cause adverse health effects and can affect multiple organ systems, primarily the respiratory and cardiovascular systems [25]. Carbon monoxide, lead, ground-level ozone, nitrogen oxides, particle pollution, and sulfur oxides are the main pollutants implicated in having an adverse effect on human health

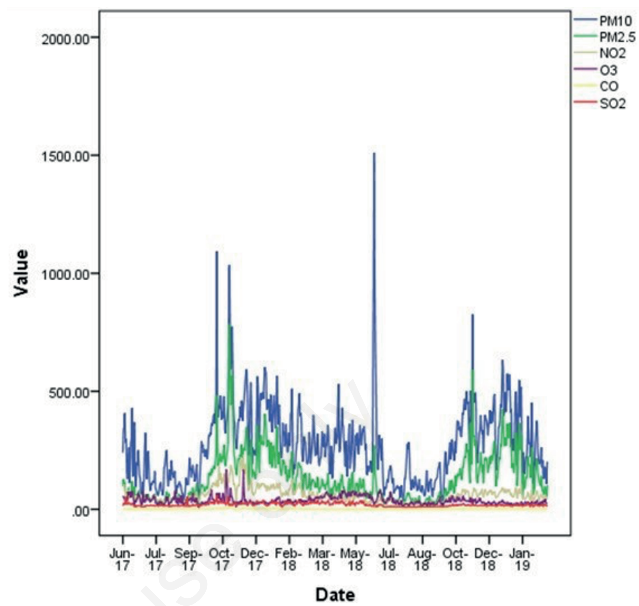

Figure 2. Levels of air pollutants during the study period. PM,particulate matter; NO_2, nitrogen dioxide; O_3, ozone; CO, carbon monoxide; SO_2, sulfur dioxide.

Table 1. Demographic and clinical characteristics of patients.

Variables		Total patients enrolled (n=11,424)
Age (mean±standard deviation)	47.6±16.1 years	
Sex	Male	6690 (58.6)
	Female	4734 (41.4)
Respiratory symptoms	Cough	10483 (91.8)
	Wheezing	5915 (51.8)
	Difficulty in breathing	10638 (93.1)
	Nasal symptoms	3268 (28.6)
Outcome at 12 hours	Ambulatory treatment	9756 (85.4)
	Admission	1612 (14.1)
	Referred	4 (0.4)
	Expired	7 (0.1)
	Left against medical advice	
Smoker	1715 (15)	
Cooking fuel used at home	Gas	11325 (99.1)
	Biomass fuel	94 (0.8)
	Kerosene	5 (0.1)
Non-smoker patients using BMF	69 (0.60)	
Diagnosis	Upper respiratory tract infection	130 (1.1%)
	Lower respiratory tract infection	1018 (8.9%)
	Pneumonia	49 (0.4%)
	Asthma	2725 (23.9%)
	Sinusitis	21 (0.2%)
	Chronic obstructive pulmonary diseases	2496 (21.8%)
	Post tubercular sequelae	2866 (25.1%)
	Others	1403 (12.3)
	Not available	716 (6.3)

BMF, biomass fuel.

[26]. The results of studies on the effect of CO on the respiratory system have been conflicting. Some studies have found that it results in worsening of lung functions, while others have shown acute protective effects of low levels of CO. The primary effect of CO exposure at high concentrations is hypoxia, resulting in confusion, headaches, and nausea. However, CO might be a marker for other noxious combustion products. [27,28]. SO_2 has been linked to admissions in asthmatic children, but a direct association with respiratory mortality and morbidity is not established [29,30]. Data from various epidemiological studies have found that PM (PM10 and PM2.5) have direct implications for respiratory mortality and morbidity. PM2.5 has a small aerodynamic diameter and, therefore, can reach the alveoli, causing further damage [31]. An increase in PM levels has been found to be associated with lung function decline, increased hospitalization for exacerbations of chronic lung diseases, and even increased mortality from pneumonia [32]. Short-term exposure to ozone has been implicated in increased hospitalization for asthma and COPD; however, data on long-term implications is very limited [33]. NO_2 has also been linked to asthma exacerbations [34]. A significant increase in ERV was observed with an increase in PM10 levels and NO_2. Peel *et al.* also observed an increase in emergency department visits for upper respiratory infections with an increase in PM10 [12]. Zheng *et al.* also showed that air pollutants are associated with significantly increased risks of asthma ERVs and hospitalizations [13]. NO_2 increase has been found to be significantly associated with ERV for asthma, and an inverse decrease in NO_2 exposure has been shown to result in a reduction of ERV [35,36]. Short-term exposure to NO_2 results in an inflammatory response in the lungs and consequential symptoms of coughing, wheezing, and difficulty in breathing [37]. Studies have shown that an increase in PM2.5 results in an increase in ERV for respiratory diseases, particularly asthma and COPD [38-40]. Few studies have reported no association between PM2.5 and asthma ERV in children [40]. Our study showed a negative association between the increase in PM2.5 levels and ERV. Since the study was conducted in tertiary respiratory care centers, it is highly likely that patients do not report to these centers for symptoms of short duration, and patients with chronic

Table 2. Change in the daily emergency visits with the increase in pollutants.

Pollutant	Lag days	Correlation coefficient with 95% CI	p
CO	1	0.3 (-5.33, 6.27)	0.9161
	2	2.29 (-3.94, 8.91)	0.4712
	3	3.61 (-3.1, 10.78)	0.2897
	4	2.85 (-4.16, 10.37)	0.4259
	5	2.97 (-4.34, 10.84)	0.4271
	6	2.97 (-4.63, 11.18)	0.4448
	7	3.66 (-4.27, 12.26)	0.3663
NO_2	1	8.79 (2.11, 15.9)	0.0078
	2	9.68 (2.33, 17.55)	0.0077
	3	5.96 (-1.76, 14.3)	0.1258
	4	7.22 (-1.12, 16.27)	0.0852
	5	5.78 (-2.96, 15.3)	0.1925
	6	6.55 (-2.67, 16.64)	0.161
	7	4.9 (-4.58, 15.31)	0.3126
O_3	1	-0.64 (-3.53, 2.34)	0.6626
	2	-0.84 (-3.88, 2.3)	0.5896
	3	-1.89 (-5.02, 1.35)	0.2404
	4	-1.65 (-4.92, 1.72)	0.3233
	5	-1.77 (-5.15, 1.73)	0.3083
	6	-2.16 (-5.65, 1.47)	0.2302
	7	-2.41 (-6.03, 1.34)	0.1955
PM10	1	5.86 (-0.9, 13.07)	0.0842
	2	8.81 (1.15, 17.05)	0.0207
	3	10.09 (1.65, 19.22)	0.0159
	4	10.74 (1.55, 20.77)	0.0185
	5	10.6 (0.82, 21.33)	0.0295
	6	12.9 (2.3, 24.59)	0.0138
	7	15.29 (3.86, 27.98)	0.0064
PM2.5	1	-13.24 (-20.42, -5.41)	<0.001
	2	-17.27 (-24.77, -9.02)	<0.001
	3	-17.94 (-26.01, -8.99)	<0.001
	4	-18.85 (-27.5, -9.17)	<0.001
	5	-18.7 (-27.94, -8.27)	<0.001
	6	-20.77 (-30.28, -9.96)	<0.001
	7	-22.57 (-32.32, -11.43)	<0.001
SO_2	1	-11.73 (-16, -7.25)	0.000
	2	-12.94 (-17.54, -8.09)	0.000
	3	-10.82 (-15.95, -5.38)	<0.001
	4	-12.16 (-17.57, -6.4)	0.000
	5	-12.12 (-17.88, -5.95)	<0.001
	6	-12.38 (-18.45, -5.85)	<0.001
	7	-11.32 (-17.74, -4.4)	0.0014

CI, confidence interval; CO, carbon monoxide; NO_2, nitrogen dioxide; O_3, ozone; PM, particulate matter; SO_2, sulfur dioxide.

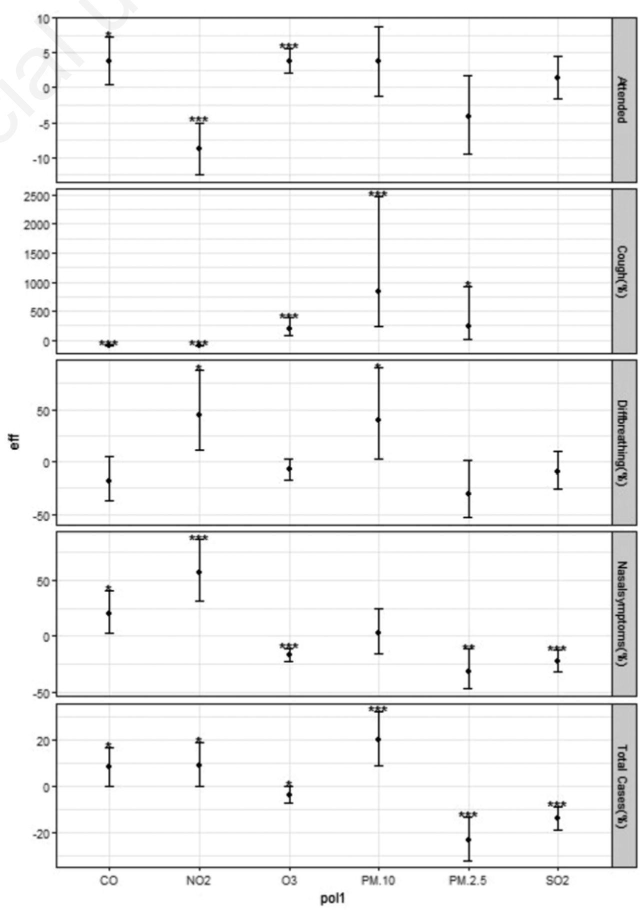

Figure 3. Change in emergency room visits and symptoms per standard deviation change increase pollutant levels. PM, particulate matter; NO_2, nitrogen dioxide; O_3, ozone; CO, carbon monoxide; SO_2, sulfur dioxide.

lung diseases opt for self-medication with over-the-counter drugs for acute symptoms. As per a study, self-prescribed medications were most commonly used for symptoms of cough, cold, and fever. Moreover, long-distance healthcare facilities were identified as the most reported reason for self-medication [41]. The association between morbidity with respiratory diseases and concentrations of SO_2 has not been defined consistently [30,42]. Our study showed a negative association between the increase in SO_2 and ERV. Since SO_2 is a gaseous compound, its emission leads to the formation of secondary particles, and some of them are converted into sulfate particulate matter. Also, other sources of pollution result in a complex mixture of pollutants, further complicating the establishment of direct associations [43]. An increase in patients presenting with difficulty in breathing was observed with a rise in O_3 levels. Ozone affects the mucous membrane of the respiratory tract and has direct irritant action that results in respiratory symptoms [44]. ERV for acute bronchitis has been shown to increase with ozone exposure [45]. The change in levels of air pollutants affects acute respiratory symptoms.

Conclusions

Overall, air pollution has detrimental effects on human health; however, further studies are needed to understand the complex interaction of pollutants and the consequential effects on respiratory health, especially on patients with chronic respiratory diseases. Such studies may help in formulating policies for air pollution control and strengthening our national programs.

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Contributions:
KS, KRJ, KM, MPG, KM, RG, contributed to the study design. All the authors have read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.