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Full Length Research Paper

An epidemiological study on effect of air pollutants on respiratory morbidity in adults of a critically polluted city of northern India

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Research into the health effects of air pollution is ongoing all over the world. This study aimed to assess the impact of air pollution on the respiratory disease in a critically polluted city of northern India. Air pollution has become a hazardous problem in India with an increase in urbanization, vehicle density and industrial smoke emission. Cross-sectional household survey was conducted in "exposed" and "reference" population. Ambient air quality data were assessed in both towns. Only the level of total suspended particulate matter (TSP) was observed to be more than permissible limit in Mandi Gobindgarh. Results of multivariate logistic regression showed that after controlling the confounding variables, cough (OR = 1.59, 95% CI 1.21-2.12, P = 0.001), phlegm (OR = 1.56, 95% CI 1.17-2.07, P = 0.003), wheeze (OR = 1.50, 95% CI 1.04-2.17, P = 0.03), chronic bronchitis (OR = 2.23, 95% CI 1.10-4.53, P = 0.03) and obstructive defects (OR = 1.86, 95% CI 1.43-2.42, P = 0.001) were significantly higher amongst the residents of Mandi Gobindgarh. Adult population of Mandi Gobindgarh has significantly more chronic respiratory morbidity as compared to that of Morinda. It is concluded that the level of TSP in the ambient air is responsible for the poor respiratory health in adults of Mandi Gobindgarh.

Key words: Air pollution, respiratory symptoms, morbidity, obstruction, restriction.

INTRODUCTION

With growing urbanization and vehicle density, urban air pollution has become a crucial problem and it is now pressing to undertake risk assessments in order to evaluate and prioritize control strategies all over the world. Respiratory diseases emerged as major health problems in the developing countries, like India where rapid urbanization has caused very high level of air pollution in some cities (Aggarwal et al., 2002). The Ministry of Environment and Forests, Government of India has identified Mandi Gobindgarh as one of the critically polluted area in the country (American Thoracic Society, 1991).

The health effects depends upon the specific chemicals to which exposure has occurred, the characteristics of the individual such as age, sex, genetic makeup, the metabolism of the chemical and the operation of confounding variables viz. personal habits, and prevalence of other diseases of primary concern from long term perspectives such as cancer, genetic defects, reproductive abnormalities, alternations of immune status and disorders of central nervous system and behavior. Some individuals are much more sensitive to pollutants than others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted.

In order to evaluate the risk aspects due to air pollution at the general population levels, several factors have to be considered, that is, exposure dose, biological effect and proportion of the exposed population. The results of these studies are difficult to interpret because of a variety of limitations mostly regarding exposure assessment and handling of co-factors (Asher et al., 1998).

Chronic obstructive pulmonary disease (COPD) is one of the leading causes of morbidity and mortality both in the industrialized and the developing countries. The burden of this respiratory disease worldwide is expected to increase and have an impact on the individual and the

Table 1. Air pollutants concentrations in ambient air.

Ambient air pollutants	Mandi Gobindgarh	Morinda
PM_{10} (µg/m^3)	110.2	77.2
TSP (µg/m^3)	890.3	291.3
NOx (µg/m^3)	27.4	7.4
SOx (µg/m^3)	29.6	8.9
O_3 (ppm)	0.05	0.03
CO (µg/m^3)	962.9	113.9

society (Karita et al., 2001). The disease contributes immensely in this country as well (Jindal et al., 2006; Jindal, 2006).

An attempt has been made in the past to estimate the gross burden of COPD in India (Jindal et al., 2001). The median values of prevalence rates from published studies were 5.0% in male and 2.7% in female population (Jindal et al., 2001). These results also substantiated by a multi-centric epidemiological study from India (Wong et al., 1999). But the role of air pollutants has not been clearly studied from India.

This study was aimed to evaluate the effects of air pollutants on respiratory morbidity among adults in representative samples of two populations, one each in industrial and a non-industrial town of Punjab.

MATERIALS AND METHODS

Description of study area

Mandi Gobindgarh is situated at a latitude of 30.66°N and a longitude of 76.31°E, having an area of 32 km^2 and population of 55,400 as per the census report for the year 2001. Whereas Morinda, which was taken as control area is situated at latitude of 30.83°N and longitude of 76.58°E having area of 7 k m^2 and population of 21,800.

Study design

Cross-sectional household survey was conducted in the “exposed” and the “reference” population with a view to collect the data pertaining to socio-demographic factors, occupational history, life style (including smoking), respiratory symptoms and lung functions. Ambient air quality data were assessed for a period of two years.

The sample size was approximately 1000 for the exposed and the reference populations. According to cluster sampling scheme, two colonies were selected in each of the towns. Interview was carried out based on a structured questionnaire. The questionnaire on respiratory symptoms was tailored on the questions listed by the British Medical Research Council, UK (Fletcher et al., 1965), American Thoracic Society (1991) and International Study of Asthma and Allergies in Childhood (ISAAC) schedules (Asher et al., 1998). The questionnaire pertained to the questions on socio-economic characteristics, household environment, respiratory symptoms, smoking history, residence and occupational history. To assess the socio-economic status, modified Kuppuswami (1981) scale Kuppuswami. Data collection was undertaken from January 2000 to December 2001. It consisted of interview and physical examination of the individual and the air sampling at the both towns.

Interview and physical examination

The individuals were interviewed by using an interview schedule. After completion of the interview, the physical examination was carried out and measurements were made for height and weight. Spirometry was performed by using a portable ventilometer (Clament Clark) as per standard guidelines.

Forced vital capacity (FVC), forced expiratory volume in first second (FEV_1), peak expiratory flow (PEF) and FEV_1/FVC% (FEV_1 as a percentage FVC) were measured. Prevalence of obstructive and restrictive diseases, were calculated (Aggarwal et al., 2002) from lung functions, that is, FVC, FEV_1 and FEV_1/FVC%.

Air sampling

Air quality monitoring was done by the high volume air sampler (HVS) (Envirotech APM 460) every week for particulate matter less than ten micron in size (PM_{10}), TSP, NOx, SOx and O_3. Weekly sampling by the organic vapour sampler (OVS) (Envirotech APM 850) was done for CO.

Statistical analysis

Chi-square test was used to test significant difference in the categorical and t-test for quantitative variables. T-test was used to compare mean values of years of residence, smoking duration and smoking index. Odds ratio and 95% confidential intervals for residence in industrial town were estimated using binary logistic regression analysis in SPSS programme.

RESULTS

Air pollution

Only the level of total suspended particulate matter (TSP) was observed to be more than permissible limit in Mandi Gobindgarh. Level of monthly means of TSP in Mandi Gobindgarh ranged from 662.1 to 1125.1 µg/m^3 while in Morinda, it ranged from 143.5 to 599.9 µg/m^3. Levels of all the pollutants were higher in Mandi Gobindgarh than in Morinda (Table 1).

Daily and yearly variations of all the parameters were

Table 2. Prevalence of cough and phlegm.

Respiratory symptoms	Mandi Gobindgarh (N=1003) (%)	Morinda (N=1001) (%)
Cough	201(20.0)*	122(12.2)
Cough during the day or at night in winter	197(19.6)*	116(11.6)
As much as three months each year	173(17.3)	80(8.0)
Phlegm	194(19.3)	116(11.6)
Twice or more times in winter during the day or night	182(18.2)	104(10.4)
Three months or more in a year	33(3.3)	43(4.3)
Two or more periods in the past three year	41(4.1)	26(2.6)

*****Between towns P<0.05.

Table 3. Prevalence of breathlessness and wheezing.

Respiratory symptoms	Mandi Gobindgarh (N=1003) (%)	Morinda (N=1001) (%)
Breathlessness on hurrying on level ground	272(27.1)	200(20.0)
Compared to people of same age walking with others	260(25.9)	192(19.2)
On walking of your own pace on level ground	159(15.9)	116(11.6)
On washing or dressing etc.	95(9.5)	59(5.9)
Wheezing	105(10.5)*	58(5.8)
Constant	54(5.4)	31(3.1)
Intermittent	52(5.2)	27(2.7)
Wheezing on provocation	68(6.8)*	33(3.3)
Worse at day	19(1.9)	13(1.3)
Worse at night	51(5.1)*	19(1.9)
No change	35(3.5)	26(2.6)

*P<0.05 between towns.

under permissible limit except TSP that was more than permissible limit in Mandi Gobindgarh. Levels of all the pollutants were higher in Mandi Gobindgarh as compared to those in Morinda.

Meteorological data obtained from Patiala observatory showing higher temperature in the summer months of year 2001 as compared to year 2000 is a reason for dispersion of pollutants that might have led to lower level of pollution in the year 2001 as compared to 2000. Average relative humidity was more while average wind velocity was comparatively less in the year 2001 as compared to 2000.

Characteristics of the study population

For the household survey, 1003 subjects were selected from the exposed and 1001 from the reference town. There was equal distribution of men and women in the two sample groups, only those with age more then 20 years were sampled.

The level of higher socio-economic status, current smoking, passive smoking, biomass fuel use, household environment such as inadequate light, inadequate ventilation and dampness, moderate to severe dust exposure, immigrants and factory workers were higher in Mandi Gobindgarh. Therefore, prevalence of respiratory morbidities was compared according to socio-economic status, smoking, biomass fuel use, dust exposure, immigrants and factory workers in the both towns.

Prevalence of chronic respiratory morbidities

It was found that prevalence of cough and phlegm in Mandi Gobindgarh was 25.6 and 25.2%, respectively in males, which was significantly higher as compared to that in Morinda (Table 2).

It was found that prevalence of breathlessness and wheezing in Mandi Gobindgarh was 21.9 and 10.9% in males, which was significantly higher as compared to that in Morinda (Table 3).

Table 4. Prevalence of respiratory diseases.

Respiratory diseases	Mandi Gobindgarh (N=1003)	Morinda (N=1001)
Chronic bronchitis*	146(14.6)*	42(4.2)
Asthma**	36(3.6)*	14(1.4)
Tuberculosis**	22(2.2)	11(1.1)

*****Between towns P<0.05. *Based on symptoms of cough with expectoration for more than three months in a year for two consecutive years; **Self reported.

Prevalence of chronic bronchitis and asthma was significantly higher in males of Mandi Gobindgarh (25.6 and 5.1%, respectively) as compared to 15.6 and 1.6%, respectively in Morinda (Table 4).

Obstructive abnormalities in males and females of Mandi Gobindgarh were 28.8 and 26.4% respectively, which was significantly higher as compared to 14.9 and 12.9% in Morinda respectively (Table 5).

The population characteristics in Mandi Gobindgarh were not similar to that of Morinda with respect to socio-economic status, smoking, use of biomass fuel, ethnicity and length of residence in the town. Some of these characteristics particularly smoking, use of biomass fuel and occupation have been shown to be associated with chronic respiratory morbidities. Therefore, prevalence of respiratory morbidity was compared in stratified analysis in smokers and non smokers, users of biomass fuel and non users of biomass fuel and among occupational socio-economic, migrant and resident groups. The prevalence of respiratory morbidities was significantly higher in Mandi Gobindgarh even in non-smokers, non-biomass fuel users, among those having higher socio-economic status, among non industrial workers and local residents as compared to Morinda (Table 6). Confounding in these variables was evaluated in multivariate analysis.

After controlling the effect of age, sex, socioeconomic status, smoking, biomass fuel use, inadequate lighting, inadequate ventilation, dampness, residence duration, dust exposure, factory workers and migrant population by using binary logistic regression models on individual symptoms, it was observed that cough had OR = 1.59 95%CI 1.21-2.12, P = 0.001. Cough, phlegm, dyspnoea, wheeze, asthma, chronic bronchitis and obstructive defects were significantly associated with poor ambient air quality. Whereas, tuberculosis and restrictive defects were not significant in the area of poor ambient air quality (Table 7). Smoking, biomass fuel, duration of residence and migration were independently associated with respiratory morbidity. The ambient air quality was poorer in Mandi Gobindgarh due to high TSP and could be responsible for high prevalence of cough, phlegm, dysponea, wheeze, chronic bronchitis and obstructive spirometric patterns observed in Mandi Gobindgarh as compared to Morinda, towns with lower level of air pollution. Similarly, association of poor air quality with chronic respiratory morbidity has been observed in other cross-sectional studies.

DISCUSSION

The acute effects of air pollution have stimulated the interest of epidemiologists and clinicians, and several studies were published focusing on the associations between adverse respiratory symptoms and concentrations of air pollutants. Time series studies have shown that air pollution is associated with increased hospital admissions and mortality due to cardiorespiratory diseases as pre-existing conditions aggravate with rise in air pollution. However, long term effects of ambient air pollution in causing chronic respiratory problems such as chronic bronchitis and asthma have been unclear.

Air quality was monitored in the study area for PM_{10}, TSP, NO_x, SO_x, CO and O_3 by using standard methods prescribed by Bureau of Indian Standards (BIS) (Indian Standard Methods for Measurement of Air Pollution (sulphur dioxide), 2001; Indian Standard Methods for Measurement of Air Pollution (suspended particulate matter), 1999; Indian Standard Methods for Measurement of Air Pollution (nitrogen oxides), 1998; Indian Standard Methods for Measurement of Air Pollution (carbon monoxide), 1999; Indian Standard Methods for Measurement of Air Pollution (ozone), 1986). Concentrations of air pollutants are compared with the standards of ambient air quality that have been set for Indian climate by CPCB, World Health Organisation (WHO) and United State of Environment Protection Agency (USEPA). In Mandi Gobindgarh, level of PM_{10}, TSP, NO_x, SO_x, CO and O_3 were significantly higher as compared to Morinda. Only the level of SPM was more than the permissible limits of CPCB and USEPA in Mandi Gobindgarh.

Only the level of TSP was observed more than permissible limit in Mandi Gobindgarh. Level of monthly means of TSP in Mandi Gobindgarh ranged from 662.1 to 1125.1 $\mu g/m^3$, while in Morinda, it ranged from 143.5 to 599.9 $\mu g/m^3$. Levels of all the pollutants were higher in Mandi Gobindgarh than in Morinda (Table 1).

Level of TSP in Mandi Gobindgarh ranged from 506.0 to 1308.5 $\mu g/m^3$, while in Morinda, it ranged from 114.0 to 480.0 $\mu g/m^3$, except one peak of 796.9 $\mu g/m^3$. PM_{10} is considered to be more sensitive parameter than TSP. Concentration of PM_{10} in Mandi Gobindgarh was also mostly more than the permissible limit of CPCB. Level of monthly mean of PM_{10} range from 50.2 to 242.6 $\mu g/m^3$ in Mandi Gobindgarh, while in Morinda, it ranged from 54.7 to 90.5 $\mu g/m^3$. The level of air pollutants in study area during year 2001 was less as compared to year 2000. Reason for this decrease in the level of TSP in 2001 could be due to the decrease in the number of industries in the year 2001 as compared to the previous years as strict enforcement against pollution spreading industries forced some of the industries to close down.

Table 5. Prevalence of spirometric abnormalities.

Spirometric abnormalities	Mandi Gobindgarh (N=909)	Morinda (N=930)
Obstruction•	250(27.5)*	129(13.9)
Mild	188(20.7)*	92(9.8)
Moderate	35(3.9)	31(3.3)
Severe	27(2.9)*	7(0.8)
Restriction••	198(21.7)	170(18.3)
Mild	155(17.0)*	122(13.1)
Moderate	35(3.8)	42(4.5)
Severe	8(0.9)	6(0.7)

***Between towns P<0.05. Obstruction•: If value of FEV_1 / FVC% was less than that of lower limit of normal (LLN) for predicated FEV_1 / FVC % value then it is known as obstruction; Mild obstructive defect if value of FEV_1 was more than that of 60%; Moderate obstructive defect if value of FEV_1 was more than 40 to 60%;Severe obstructive defect if value of FEV_1 was less than 40%. Restriction••: If value of FEV_1 / FVC % was more than or equal to that of LLN for predicated FEV_1 / FVC % value and If value of FVC was less than that of LLN for predicated FVC value, then it is known as restriction. Mild restrictive defect if value of FVC was more than 60%; Moderate restrictive defect if value of FVC was more than 40 to 60%; Severe restrictive defect if value of FVC was less than 40%.

Table 6. Distribution of population characteristics.

Variables	Mandi Gobindgarh (N=1003)	Morinda (N=1001)
Higher socio-economic status	28(2.8)*	107(10.7)
Current smoking	318(31.8)*	210(21.0)
Passive smoking	361(36.0)*	132(13.2)
Biomass fuel use	705(70.3)*	444(44.4)
Inadequate lighting	177(17.6)*	120(12.0)
Inadequate ventilation	264(26.3)*	178(17.8)
Dampness in house	124(12.4)*	72(7.2)
Mattress use	813(81.1)	743(74.3)
Carpet use	547(54.5)	476(47.6)
Presence of insects	963(96.0)	954(95.3)
Overcrowding	697(69.5)	765(76.4)
Moderate to severe dust exposure	407(40.7)*	267(26.7)
Immigrants	507(50.5)*	187(18.7)
Factory workers	200(19.9)*	0.0(0.0)

*Between towns P<0.05.

The prevalence of cough, phlegm, breathlessness and wheezing in Mandi Gobindgarh were 25.6, 25.2, 21.9 and 10.9% in males, and 14.5, 13.6, 32.3 and 10.0% in females, respectively, whereas, prevalence of these symptoms in Morinda were 14.4, 12.6, 15.0 and 6.4% in males, and 9.9, 10.6, 24.9 and 5.2% among females respectively. Kamat and Doshi (1987) reported the prevalence of chronic cough in the range to be 1.7 to 5.1% and dyspnoea range from 3.2 to 7.2% in Mumbai. Chronic cough was 12 and 11.2% in Parel and Lava, whereas dyspnoea was 53 and 13%, respectively.

In this study, prevalence of self reported asthma in Mandi Gobindgarh was 5.1 and 2% among males and females, respectively whereas in Morinda, it was 2 and 0.8%, respectively. Jindal et al. (2001) have reported asthma prevalence of 3.9% in urban males, 3.9% in rural males, and 1.3% in both urban and rural females from north India (Jindal et al., 2001). Gupta et al. (2001) have reported asthma in 3.3% children who were not exposed to environmental tobacco smoke. According to ISSAC (1998) study, asthma prevalence was 2.8% among children in Chandigarh.

Table 7. Association of residence in poor air quality town with chronic respiratory morbidities.

Variable	Odds ratio	95% confidence interval		Significance
		Lower	Upper	P-value
Cough	1.59	1.21	2.21	0.001
Phlegm	1.56	1.17	2.07	0.003
Dysponea	1.41	1.09	1.78	<0.01
Wheeze	1.52	1.05	2.19	0.03
Chronic bronchitis	3.13	2.11	4.64	<0.001
Asthma	2.27	1.12	4.59	0.03
Obstructive defects	1.89	1.45	2.45	<0.001
Restrictive defects	1.66	0.98	1.66	0.07
Tuberculosis	1.33	0.56	3.16	0.5

Logistic regression model include age, sex, socio-economic status, smoking, use of biomass fuel, inadequate ventilation and lighting, dampness in house, mattress or carpet use and overcrowding.

In this study, chronic bronchitis prevalence was 19.6% among males and 9.6% among females in Mandi Gobindgarh and 5.4 and 3.0%, respectively in Morinda et al. (2001), who reviewed 14 studies, to estimate the gross burden of chronic obstructive pulmonary disease (COPD) (Jindal et al., 2001). The median values of different prevalence rates were 5% in male and 2.7% in female population. In three urban areas of Mumbai, prevalence of chronic bronchitis ranged from 2.3 to 4.5% (Kamet and Doshi, 1987). Bakke et al. (1991a) has reported chronic bronchitis (Bakke et al., 1991b) in 5.4%.

In this study, spirometery standards developed by Jindal and Wahi (1990) for north India population were used. The prevalence of obstructive defect was observed in 29.0% in males and 14.7% among females in Mandi Gobindgarh and 24.2 and 12.6% among males and females, respectively in Morinda. Mild obstructive defects were much more common. In Mandi Gobindgarh, males and females were having mild obstructive defect but moderate to severe defect was in 7.6 and 5.9% respectively. In Morinda, the prevalence of moderate to severe obstructive defect was observed in 2.8 and 5.4% among males and females, respectively. According to the study done by Bakke et al. (1991a), spirometric patterns (FEV_1/FVC< 0.7 and FEV_1, <80% of predicted values) was observed in 4.5% of the population.

Prevalence of self reported tuberculosis among males and females was 2.9 and 1.4% in Mandi Gobindgarh, whereas in Morinda, it was 2.0 and 0.1%, respectively. The prevalence of tuberculosis was reported to be 0.4% in India.

Chhabra et al. (2001) also found that subjects who were exposed to poor ambient air quality due to high level of SPM had poor lung function tests in Delhi. Similarly, studies by Detels et al. (1981) and Pope et al. (1991) have also reported association of poor air quality and higher respiratory morbidity in USA. Kamat and Doshi (1987) showed a higher morbidity with raised levels of air pollution in 3 urban and a rural community of Mumbai. In the respective 4 areas, standardized prevalence were: for dyspnoea 7.3, 6, 3.2 and 5.5%; for chronic cough 5.1, 2.7, 1.7 and 3.3%; for chronic bronchitis 4.5, 4.5, 2.3 and 5.0%.

In the present study, association between poor ambient air quality was found with cough (OR = 1.59, 95%CI: 1.21-2.12, P = 0.001) and phlegm (OR = 1.56, 95%CI 1.17-2.07, P = 0.003). This is supported by the study of Wong et al. (1999), which shows significant effects of air pollution on morning cough (OR = 1.65, 95%CI: 1.03–2.64), phlegm in the morning (OR = 1.40, 95%CI: 1.03–1.92), phlegm in the day or night (OR = 1.63, 95%CI: 1.10–2.42) and phlegm for three months (OR = 1.70, 95%CI: 1.13–2.56) in nonsmoking women in high polluted area. The odds ratio (OR) for the distinct effect was 1.55, which is consistent with Dockery's statements that the health effects of air pollution observed in the cites of the United States would usually be weak, with a relative risk of less than 2 and often less than 1.5 for typical exposure (World Health Organisation, 1987).

In this study, subjects exposed to poor ambient air quality were significantly associated with obstructive spirometric patterns (OR = 1.89, 95%CI 1.45-2.45, P<0.001). These results are in accordance with study done by Karita et al. (2001) who reported an increase in prevalence of obstructive changes in the peripheral airways among traffic police in Bangkok. Ostro et al. (1991) found that air borne H^+ was significantly associated with several indicators of asthma status, including moderate or severe cough and shortness of breath.

Zemp et al. (1999) in a cross-sectional study in random population samples of adults at eight study sites in Switzerland reported independent, positive association between annual mean concentrations of NO_2, total suspended particulates, and particulates of less than 10 µm in aerodynamic diameter (PM_{10}) with prevalence of chronic phlegm production, chronic cough or phlegm production, breathlessness at rest during the day, breathlessness during the day or at night, and dysponea on exertion. They found no associations with wheezing without cold, current asthma, chest tightness or chronic cough. Among never-smokers, the odds ratio (95% CI) for a 10 µm/m^3 increase in the annual mean concentrations of PM_{10} was 1.35 (1.11 to 1.65) for chronic phlegm production, 1.27 (1.08 to 1.50) for chronic cough or phlegm production, 1.48 (1.23 to 1.78) for breathless during the day, 1.33 (1.14 to 1.55) for breathlessness during the day or night and 1.32 (1.18 to 1.46) for dyspnoea on exertion. Similar associations were also found for former and current smokers, except for chronic phlegm production. The observed associations remained stable when further control was applied for environmental tobacco smoke exposure, past and current occupational exposures, atopy, and early childhood respiratory infections when restricting the analysis to long-term residents and to non alpine areas, and when excluding subjects with physician-diagnosed asthma (Wong et al., 1999).

Peter et al. (1999) conducted a ten year prospective cohort study on Southern California children, with a study design focused on four pollutants: ozone, particulate matter, acids and nitrogen dioxide (NO_2). Wheeze prevalence was positively associated with levels of both acid (OR = 1.45; 95%Cl, 1.14.83), and NO_2 (OR = 1.54; 95%Cl, 1.08-2.19) in boys. In the present study, dyspnoea (OR = 1.41, 95%CI 1.09-1.78, P = 0.01) and asthma (OR = 2.27, 95%CI 1.12-4.59, P = 0.03) was significantly associated with poor ambient air quality (Peter et al., 1999). Chhabra et al. (1999) studied the magnitude of the problem of childhood asthma in India and the factors influencing its occurrence. Multiple logistic regression analysis showed that male sex, a positive family history of atopic disorders, and the presence of smokers in the family were significant factors influencing the development of asthma, whereas socio-economic class, air pollution (total suspended particulates) and type of domestic kitchen fuel were not associated with asthma.

Chhabra et al. (2001) compared nonsmoking residents of lower- and higher-pollution zones in Delhi stratified according to socioeconomic levels and sex. Chronic cough, chronic phlegm and dyspnoea (but not wheezing) were significantly more common in the higher-pollution zone in only some of the strata. Lung functions of asymptomatic nonsmokers were consistently and significantly better among both male and female residents of the lower-pollution zone (Chhabra et al., 2001).

Several times series studies have shown correlation of air pollution with hospital admission and cardiorespiratory mortality. A study by Pande et al. (2002) on outdoor air pollution and emergency room visits at All India Institute of Medical Sciences (AIIMS) in Delhi has shown that emergency room visits for asthma, chronic obstructive airway disease (COAD) and acute coronary events increased by 21.30, 24.90 and 24.30%, respectively, on account of higher than acceptable levels of pollutants (Pande et al., 2002). The study of Sunyer et al. (1993) showed that sulphur dioxide and black smoke concentrations in the urban air of Barcelona were associated with the number of COPD emergency room admissions in both winter and summer (Sunyer et al., 1993). Burnett et al. (1995) studied the association of daily cardiac and respiratory admissions of 168 cases in acute care hospital in Ontario, Canada, with daily levels of particulate sulphates examined over the six year period of 1983 to 1988. A 13 µg/m^3 increase in sulphates recorded on the day prior to admission (the 95th percentile) was associated with a 3.7% ($p<0.0001$) increase in respiratory admissions and a 2.8% ($P<0.0001$) increase in cardiac admission. After adjusting for ambient temperature and ozone, similar increased respiratory admissions were observed in the period of April to September (3.2%) and in the period of October to March (2.8%). Results of study conducted by Chew et al. (1999), shows that ambient air pollutant levels, in particular, those of SO_2, TSP and NO_2 were consistently associated with emergency room visits for asthma in children. Damia et al. (1999) showed that air pollutants (black smog and SO_2) correlate significantly with emergency room admissions for asthma (SO_2 [r = 0.32], black smoke [r = 0.35]); however, multiple regression analysis showed that black smoke was the only significantly predicator of weekly visits.

Air pollutants cause damage to respiratory endothelium, Pande et al. (2002) found that people living in areas with high air pollution have increased levels of soluble intercellular adhesion molecule-1, a marker for endothelial activation. Chronic respiratory morbidities such as chronic bronchitis occur after a prolonged exposure.

A cross-sectional study was carried out by Kumar et al. (2004), to estimate the prevalence of chronic respiratory symptoms (cough, phlegm, breathlessness or wheezing), that is, 27.9 and 20.3% and obstructive ventilatory defect, that is, 24.9 and 11.8%, in the study and reference towns, respectively. Logistic regression analysis showed that residence in the study town was independently associated with chronic respiratory symptoms (odds ratio [OR] = 1.5; 95% confidence interval [CI] = 1.2, 1.8; $p<0.001$) and spirometric ventillatory defects (OR = 2.4; 95% CI = 2.0, 2.9; $p<0.001$) after controlling for other demographic effects (Kumar et al., 2004).

Beatty and Shimshack (2011) found that school bus retrofits induced reductions in bronchitis, asthma and pneumonia incidence for at-risk populations. Richardson et al. (2011) found a dose-response relationship between PM_{10} and respiratory disease mortality, including at concentrations below the existing annual average guideline value of 20 µg m^{-3}.

However, socioeconomic inequalities in respiratory disease mortality were not significantly elevated with PM_{10} exposure.

Findings of the study clearly show that poor ambient air quality at Mandi Gobindgarh was associated with high prevalence of cough, phlegm, dysponea, wheeze, chronic bronchitis, asthma and obstructive but not with tuberculosis and restrictive defects. This study establish further evidence that long-term exposure to air pollution of rather high levels of TSP is associated with higher prevalence of respiratory symptoms in adults.

It can be concluded that the level of TSP was higher in Mandi Gobindgarh and it is an important contributor in causation of respiratory morbidity and abnormal lung functions. An association between chronic respiratory morbidities with air pollution seems to be causal in nature. Level of PM_{10}, NOx, SOx, O_3 and CO were also more in Mandi Gobindgarh than Morinda but were below the permissible limit. Stijn et al. (2012) study results showed modest differences on a regional level. At the local level, however, time-activity patterns indicated larger differences in exposure and health impact estimates, mainly for people living in more rural areas.

Sousa et al. (2012) study suggests that the ambient levels of air pollutants experienced in Rio de Janeiro between 2000 and 2005 were linked to the number of hospitalizations for respiratory diseases among children and elderly. Results showed an excess risk of hospitalization for respiratory disease higher than 2% per 10 µg m^{-3} increase in PM_{10} concentrations for children under 5 years old, 2% per 10 µg m^{-3} increase in SO_2 for elderly above 65 years old and about 0.1% per 10 µg m^{-3} increase in CO for children under 1 year and elderly (Sousa et al., 2012).

The air pollution levels are alarmingly high in Indian metropolitan towns. The World Health Organization (1998) estimated 3 million premature deaths per year, mainly in acute and chronic respiratory infections, attributed to exposure to air pollution on a worldwide basis. In this study, most of the subjects were permanent residents of the town or were long time migrants to Mandi Gobindgarh. They were exposed to air pollution since industrialization started in this town about 60 to 70 years ago. So, this long term exposure of TSP was an important pollutant in high prevalence of respiratory morbidity and abnormal lung functions in adults of this critically polluted city of northern India.

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