Air pollution is one of the serious problems faced by the people in the developing countries like India. The urban areas in India have not only experienced a rapid growth of population but also a huge number of vehicles. Primary pollutants like carbon monoxide, hydrocarbons, sulphur dioxides, nitrogen oxides etc. and secondary pollutants like photochemical smog and acid rain are found to be present in the atmosphere. Automobiles exhausts play an important role in the formation of pollutants in urban environment which adversely affect the health of human beings in the form of various respiratory illnesses like asthma, chronic bronchitis, lung infection and chronic obstructive pulmonary disease etc.

The decrease of peak expiratory flow (PEF) in children with asthma has been noted in areas with heavy traffic density. Parallel to the increase in air pollution, there has also been a rapid increase in the global incidence of allergic diseases such as asthma and rhinitis in the last two decades, which cannot be attributed to genetic changes, and is assumed to be related to changes in environmental factors. Recent epidemiological data support the theory that atopic children may constitute a group of individuals that run a heightened risk of developing negative health effects following exposure to airborne particles. At high ambient concentrations, well defined and marked systemic pulmonary inflammatory response is also observed. Diesel exhaust contains various harmful substances and in association with air pollution cause asthma in children. PM10 is often associated with asthma and chronic cardiovascular and respiratory health problems. The PM10 particulate matter in particular has a potential to induce acute respiratory morbidity. Therefore, the present research work was conducted to evaluate the effect of air pollution on human beings. The aim of this study was to investigate potentially abnormal lung function and respiratory symptoms in subjects living in an area with heavy motor traffic and major permanent air pollution, and in a population living in a low pollution area.

**MATERIALS AND METHODS**

Rohtak, a city located 70 km away from Delhi (Capital of India) towards west has an area of 441100 hectares. Being very near to a metropolitan city, it may be one of the reasons for faster urbanization which in turn led to tremendous increase in the number of vehicles in the city. To study the ambient air quality, six sampling sites viz. University campus (low traffic density, residential site), Delhi bye pass (high traffic density), Medical mor (city centre, moderate traffic), New bus stand (Moderate traffic density having light and heavy vehicles), Bhiwani stand (high traffic density) and Hissar road (industrial...
area with high traffic density) were selected in the city on the basis of vehicular density and population. Air pollution is a mixture of particles and gases in the ambient air, which have been associated with adverse health effects. The Environmental Protection Agency (EPA) has designated some of these components as "criteria pollutants" to be regulated under the Clean Air Act. The criteria pollutants monitored at Rohtak city include sulphur dioxide, nitrogen dioxide, ozone, suspended particulate matter, heavy metals (Lead, Cadmium, Zinc, Nickel, Copper), benzene, toluene and xylene (BTX).

**Sampling and Procedure:** In the present study, ambient air quality was monitored by using 'High Volume Sampler' (Envirotech APM 415-411) for eight hours daily for suspended particulate matter and four hours daily for gaseous pollutants in winter, summer and monsoon seasons with a frequency of once in a week.

**Selection of study areas:** Two sites were selected out of six sites- one as highly polluted area (HPA) and other as low polluted area (LPA).

**Study design:** The Ethics Committee of Pt. B.D Sharma University, Rohtak granted approval of the study design and the examination protocol. Cross-sectional study was carried out to measure the prevalence of health outcomes or determinants of health in a population at a point in time or over a short period.

**Subject selection:** A sample of 500 people each was taken up from both low polluted and high polluted sites. An inclusion criterion for the study was that the person should be living and working in the selected areas for more than 1 year. The age group of the person selected for the study was 15-45 years and be a non-smoker. The study population was disaggregated into three age groups (15-25, 26-35 and 36-45 years). Informed consent was taken from the concerned study subjects during the study.

**Collection of health outcomes:** The subjects were interviewed with a standardized respiratory questionnaire based on American Thoracic Society (ATS) to obtain information about their personal characteristics.

**Pulmonary Function Test (PFT):** Pulmonary function tests were performed to assess lung function and determine the degree of damage to the lungs using the device spirometer (Datospir Micro B). The spirometric test was performed according to American Thoracic Society\(^\text{10}\). The spirometer coupled with computerized data acquisition software was used. The test module was activated and the subject was given proper instructions about the procedure to be performed. All the pulmonary function tests were done on the subjects comfortably seated in an upright position, following the suggestions of the American Thoracic Society. The subject was connected to the mouthpiece and was asked to breathe in and out to familiarize himself with the equipment. During the test the subject was adequately encouraged to perform their optimum level and also a nose clip was applied during the entire maneuver. Pulmonary function indices used in the analyses are expressed as the percentage of the predicted values based on the subject-specific sex, age, height and weight. The acceptable values of forced vital capacity (FVC), forced expiratory volume at one second (FEV1), peak expiratory flow (PEF), and ratio of FEV1/FVC were obtained from the under study in accordance with ATS criteria.

**Statistical analysis:** Statistical analysis was carried out with the help of SPSS. Multivariate analysis of variance (MANOVA) was used for the comparison of different air pollutants. MANOVA was also used for the comparison of all the six sites. The data of pulmonary function tests analysis of two sites subjects were compared using 't' - test.

**RESULTS AND DISCUSSION**

**Multivariate Analysis of Variance (MANOVA):** The multivariate test resulted in significant difference between the levels of pollutants over various sites in all the three seasons. Tukey's test of multiple comparisons was conducted to find out the sites in which concentration of pollutants differed significantly. Insignificant difference was observed between the two sites i.e. Hissar road and Bhiwani stand. However the pollutants concentration were significantly different from the rest i.e. University campus, Medical mor, New bus stand and Delhi byepass. According to the observation the difference was in negative direction with site University campus and in positive direction with sites Hissar road and Bhiwani stand. The analysis clearly indicated that the pollutant concentration was least in University campus and maximum in Hissar road and Bhiwani stand. The analysis clearly indicated that the pollutant concentration was least in University campus and maximum in Hissar road and Bhiwani stand. Concentration of SPM was found to be highly significant in all the three seasons with all other pollutants i.e. SPM was having the highest concentration values in comparison to all other pollutants. The other pollutants which were found to be significantly higher were SO\(_2\) and NO\(_2\). However there values
Comparison of symptoms between two population groups: The individual symptoms were analyzed with the help of a respiratory questionnaire on the subjects of both sites. Based on the answers of the questionnaire, it was compared that the symptoms, wheezing (p>0.05), catch breath (p>0.05), chest illnesses (p>0.05) and itching or rash (p>0.05) were statistically insignificant at 5 percent level of two population group. The symptoms, running nose, sneezing bouts, throat irritation, cough, phlegm production, breathing difficulty, ear discharge, eye irritation and watering, shortness of breath and blocked nose of HPA subjects were significantly different from LPA subjects. It was also observed at both the sites that number of patients had multiple symptoms like a subject had the problem of cough and running nose at one and the same time. Numbers of symptoms were observed more in HPA subjects as compared to LPA subjects (Table 1). It was also observed that the subjects who were living more than five years had more number of symptoms in comparision.

Pulmonary Function Test (PFTs): The variations in the lung parameters Forced Vital Capacity (FVC), Forced Expiratory Volume in the first 1 second (FEV1), FEV1/FVC and Peak Expiratory Flow (PEF) among the population of high polluted area and low polluted area were observed (Table 2). Highly significant difference (p<0.001) was observed in the parameters of FVC, FEV1 and FEV1/FVC of the two sites subjects and significant difference was observed in PEF (p<0.01). The test was performed on 500 subjects at both sites. A decrease in the percentage of FVC, FEV1, FEV1/FVC and PEF was observed in the subjects of high polluted area as compared to low polluted area subjects. A large difference was observed in the FEV1 percentage between two population groups. The comparison was made between the PFTs of different groups (Fig. 2). The pulmonary function test values of the subjects of low polluted area of different groups are summarized in Fig. 3. The parameters i.e. FVC, FEV1 and PEF values were found much lower in Group-3 (who had been living in high polluted area more than 5 years) as compared to Group-2 and 1. Ratio of FEV1/FVC value was observed less in Group 3 as compared to Group1 and more than Group 2. The results reveled that

Table 1. Number of respondents reporting specific ailments

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>HPA (No. of subjects)</th>
<th>LPA (No. of subjects)</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running nose</td>
<td>68</td>
<td>45</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>Sneezing bouts</td>
<td>90</td>
<td>30</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Throat irritation</td>
<td>50</td>
<td>30</td>
<td>P&lt;0.01</td>
</tr>
<tr>
<td>Cough</td>
<td>180</td>
<td>60</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Phlegm production</td>
<td>90</td>
<td>30</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Breathing difficulty</td>
<td>82</td>
<td>50</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Wheezing</td>
<td>60</td>
<td>44</td>
<td>P=0.06*</td>
</tr>
<tr>
<td>Ear discharge</td>
<td>61</td>
<td>30</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Eye irritation &amp; watering</td>
<td>96</td>
<td>61</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Shortness of Breath</td>
<td>78</td>
<td>55</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>Catch Breath</td>
<td>30</td>
<td>24</td>
<td>P=0.197*</td>
</tr>
<tr>
<td>Blocked nose</td>
<td>98</td>
<td>43</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Chest illnesses</td>
<td>35</td>
<td>20</td>
<td>P=0.163*</td>
</tr>
<tr>
<td>Itching or Rash</td>
<td>100</td>
<td>80</td>
<td>P=0.051*</td>
</tr>
</tbody>
</table>

Note: 500 subjects were examined in each area.
*Insignificant at 5% level

Table 2. Spirometry findings (percentage predicted)

<table>
<thead>
<tr>
<th>Maneuvers</th>
<th>High Polluted Area</th>
<th>Low Polluted Area</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>78.83 ± 20.35</td>
<td>86.53 ± 22.13</td>
<td>P&lt;0.001**</td>
</tr>
<tr>
<td>FEV1</td>
<td>73.66 ± 20.02</td>
<td>84.80 ± 22.33</td>
<td>P&lt;0.001**</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>93.32 ± 11.51</td>
<td>98.93 ± 12.78</td>
<td>P&lt;0.001**</td>
</tr>
<tr>
<td>PEF</td>
<td>72.28 ± 15.20</td>
<td>75.71 ± 19.15</td>
<td>P&lt;0.01</td>
</tr>
</tbody>
</table>

[**Highly significant, *Significant] were lower then the SPM values. The concentration of rest of the pollutants; SO₂, SPM, Cd, Pb, Zn, Ni, Cu, benzene and xylene had significant values in comparison to NO₂ and SPM. With the help of MANOVA, it was observed that maximum concentration of pollutant was at Hissar road and minimum at University campus. It was clear that University campus was least polluted site, while Hissar road was highly polluted area.

Respiratory Survey: The two population groups, one from Hissar road (High polluted area) and other from University campus (Low polluted area), were selected for the study. A sample of 500 people each was taken up from both High Polluted Area (HPA) and Low Polluted Area (LPA). The exposure levels in the study population were measured by the duration of stay of subjects in the study area as 1-2 years, 2-5 years and above 5 years.
those subjects who were living at high polluted area from more than 5 years had decline in lung functions as compared to the other two groups. This type of decline in pulmonary function values were not observed in low polluted area subjects. It means pollution was responsible for decline in pulmonary function values at high polluted area.

In the present study, the concentrations of SPM, \( \text{NO}_2 \) and \( \text{SO}_2 \) were observed maximum in winter season in comparison to summer and monsoon season. During the winter season there is increased atmospheric stability which in turn leads to less general circulation and thus more stagnant air masses. It prevents an upward movement of air, hence atmospheric mixing is retarded and pollutants are trapped near the ground. Agarwal et al.,10 study focuses on assessing the status of respiratory morbidity in Delhi over a four years period from 2000-2003. The study showed that winter months had greater exposure risk as pollutants often get trapped in the lower layers of atmosphere resulting in high concentrations. The study site Hisar road is an industrial area having lots of workshops with heavy traffic density and frequent traffic jams, resulting in building up of air pollutants in that area. This ultimately leads to more exposure to people residing and working in that area. On the other hand the site i.e. University campus is clean open area with lots of greenery there and also less traffic density and consequently less exposure to its inhabitants.

In the present study most of the parameters were less in the subjects of high polluted area as compared to the subjects of low polluted area. This finding indicates the restrictive nature of pulmonary involvement in the study group. Stern et al.,12 reported regional differences of 1.7 and 1.3% for FVC and FEV1 between two areas (one urban, one rural) of Canada with relatively large differences in annual concentrations of \( \text{O}_3 \), \( \text{SO}_2 \), and \( \text{NO}_2 \) and somewhat smaller differences in PM10. Associations between air pollution and various health-related outcomes have been previously reported by several investigators. One group recently reported that children, living in areas of higher ambient air pollution (areas with higher levels of particulate matter with a mean diameter of 10 µm, \( \text{NO}_2 \), and acids) have measurably slower annual rates of lung function growth, as measured by mean annual changes in FEV1, forced expiratory flow at 75% of FVC (FEF75), or maximal mid expiratory flow (MEF)13. When the results of PFTs of two populations compared age-wise (Figs. 4, 5) it was found that the values of FVC, FEV1, FEV1/FVC and PEF were lower in the subjects of HPA in comparison to LPA subjects of same population group.

Total exposure of an individual to pollutants is determined by the concentration of pollutants and the duration of exposure. The exposure levels in the study population were measured by the duration of stay of subjects in the study area as up to 1 years, 2-5 years and above 5 years. Kumar et al.,14 reported that person with less duration of exposure were found to have more compromised PFTs values as compared to those with more exposure, since it was observed that as duration increases the acute symptoms subside. Kumar et al.,14 reported similar findings where the lung functions such as forced expiratory volume, forced vital capacity and peak expiratory volume (PEV) were found to be much lower than normal. In another study that compared the ventilatory functions of two groups of school children of Kolkata, one within CMA (study) and another in an area with better ambient air quality, the observations were indicative of a statistically significant impairment of lung functions (PEFR) in the study group exposed to higher concentration of pollutants in the ambient air15. It has been previously reported that long-term exposure to air pollutants from traffic related sources reduce lung function16-17 and influence chronic respiratory diseases16. Furthermore, long-term exposure to air pollutants is known to be associated with cardiovascular mortality and increased hospital admissions18. COPD and pulmonary function were strongest affected by PM10 and traffic related exposure19.

The prevalence of air borne disease was more in high polluted area as compared to low polluted area. This could be due to high levels of air pollutants in their environment specially the suspended particulate matter, as these particulates tend to deposit in alveoli and slow down the exchange of oxygen with carbon dioxide in the blood causing shortness of breath. The individual symptoms of different age groups were analyzed and it was observed that the subjects residing in high polluted area, irrespective of age were likely to have more chances of suffering with the symptoms related to pollution compared to the subjects residing in low polluted area. The variability across subjects being larger for FVC (reflecting large airway effects) than FEF25-75% (reflecting effects on small airways) was also observed by Kinney et al.,21 although they studied the effects of short-term pulmonary change in association with ozone. The result obtained in the study provide important information for controlling air quality and decreasing the harmful effects of
pollutants on the health of the population of an inhomogeneous urbanized territory.

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