Effect of Exposure to Toxic Gas on the Population of Bhopal:
Part II—Respiratory Impairment

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The respiratory status of 783 cases, of either sex exposed to the toxic gas was investigated. Lung spirometry revealed 39% prevalence of ventilatory impairment in the affected population. The female population exhibited a higher prevalence (44.1%) of pulmonary abnormalities in contrast with the male population (33.9%). The toxic gas inhalation produced three patterns of respiratory disorders as indicated by simple spirometric tests. Bronchial obstruction was recorded in 3.7% male and 3.6% female population respectively, while restrictive pulmonary defect was noticed in 13.4% cases. The combined obstructive-cum-restrictive ventilatory disorder was observed in 22.2% population. The possible mechanisms involved in the pulmonary dysfunction induced by toxic gas are discussed.

Exposure to the toxic gas caused various pulmonary abnormalities resulting in a number of respiratory symptoms, viz, cough, dyspnoea, chest pain, etc. in the population of Bhopal. No epidemiological study is so far reported in the literature involving exposure to the human population to the toxic gas. Some studies had been conducted with isocyanates. Cumulative effect on lung function of the persons exposed to toluene diisocyanate (TDI) has been reported. Significant decrease occurred in FVC, FEV₁, PEFR, FEF₅₀% of VC on account of TDI exposure. A recent study has suggested that infiltrated lung diseases with pulmonary function abnormalities may occur in workers exposed to TDI.

Materials and Methods
Spirometry was performed in 783 cases (371 males and 412 females) examined in the respiratory screening programme during February/March 1985 at Bhopal. The subjects who were unable to perform the spirometric manoeuvres were excluded from the study. Among the 371 male cases, there were 179 (48.7%), non-smokers and 172 (51.7%) smokers while in the female population there were no smokers.

The spirometric lung functions were recorded using calibrated Vitalograph Spirometer in standing position with nose clip on. The spirometer was regularly checked for calibration of volume and speed statically and dynamically by air displacement method at ATPS (normal barometric pressure of 760 mm Hg, air saturated with water vapour). The following parameters were recorded:
1. Vital capacity (VC); 2. Forced vital capacity (FVC); 3. Forced expiratory volume in 0.75 sec (FEV₀.₇₅); 4. Forced expiratory volume in 1 sec (FEV₁); 5. FEV₁/FVC ratio; 6. Indirect maximum breathing capacity (IMBC); 7. Air velocity index (AVI).

The population exposed to toxic gas was asked to perform in the manner demonstrated to them, at least three VC and FVC manoeuvres. The values from the largest of the three reproducible curves were taken into consideration and expressed at body temperature and ambient pressure saturated with water vapour (BTPS). IMBC was calculated from FEV₀.₇₅ by multiplying it by 40. AVI was calculated from the predicted VC and IMBC values as follows:

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AVI = \frac{\text{% of normal IMBC}}{\text{% of normal VC}}
\]

Normal value of AVI was considered to be 1.0. Higher values indicated restrictive pattern and lower values obstructive pattern of respiratory impairment. The FEV₁/FVC percentage between 70 and 80 was considered normal and values less than 70% indicated central airway obstruction.

Peak expiratory flow rate (PEFR) was recorded with Peak Flow Meter (Wright Standard Model, UK) and the highest of the three values attained was recorded.

The predicted normal values for the various lung function tests were derived from the regression equations laid down for healthy north Indian population. For the female population, the predicted values were calculated from the prediction equations laid down for healthy women. The pulmonary impairment was classified according to Rastogi et al. as follows:
1 Restrictive VC or FVC less than 80% of the predicted values
2 Obstructive FEV₁/FVC ratio less than 70%
3 Combined or mixed FVC less than 80% of the predicted value and FEV₁/ FVC ratio less than 70%

Further classification of pulmonary impairment was done as follows:
1 Mild respiratory impairment, between 61 and 80%.
2 Moderate respiratory impairment, between 40 and 60%.
3 Severe respiratory impairment, less than 40%.

Statistical procedure—The lung function test results were analysed by applying Student's paired/unpaired t test in the study population. Chi square test was used for the determination of the significance of the prevalence of various categories of respiratory impairment in the male and female population exposed to the toxic gas.

Results
The physical characteristics of the male and female population studied for lung function tests are detailed in Table 1. Sexwise no significant differences were observed in their mean ages. In the male population, the age and height differences between smokers and non-smokers were noticed (P<.001 and P<.05 respectively). The mean values of anthropometric measurements of the population suffering from respiratory impairment are shown in Table 2. In the male population, the mean age of the cases with restrictive lung disorder was significantly (P<.05) less than the mean values recorded in obstructive and mixed lung abnormality cases. While in the female population, the mixed respiratory impairment cases were older than the other cases.

Data in Table 3 show no significant difference in the prevalence of pulmonary abnormality between the smokers (37.5%) and non-smokers (31.1%).

Prevalence of obstructive respiratory impairment in the study population is detailed in Table 4. Sexwise no significant difference was observed in the prevalence of airway obstruction in the lungs. Smoking exhibited a significant influence on the prevalence of bronchial obstruction (P<0.05). Mild airway obstruction was noted in 3% of the population examined. Mild bronchial obstruction was equally prevalent in the male and female population. Smokers exhibited a significantly higher prevalence (5.7%) in comparison with non-smokers (P<0.05). Sexwise, it was noted that both male and female populations were equally affected by the severe broncho-spasm.

Prevalence of restrictive respiratory impairment is presented in Table 5. 13.4% population suffered from lung restriction. However, sex and smoking habits had no effect on it. Mild restrictive lung impairment was prevalent in 12.3% cases. The results showed a significantly higher prevalence of restriction in the male population (P<0.05). Moderate

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Physical Characteristics of Population Exposed to the Toxic Gas</th>
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</thead>
<tbody>
<tr>
<td>Sex and smoking habits</td>
<td>N</td>
</tr>
<tr>
<td>Male Population</td>
<td>371</td>
</tr>
<tr>
<td>Non-smokers</td>
<td>179</td>
</tr>
<tr>
<td>Smokers</td>
<td>192</td>
</tr>
<tr>
<td>Female population</td>
<td>412</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Physical Characteristics of the Population showing Respiratory Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical characteristics</td>
<td>Males (N = 120)</td>
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<tr>
<td>Age (yrs)</td>
<td>40.4 ± 3.3</td>
</tr>
<tr>
<td>Height (cms)</td>
<td>161.2 ± 1.7</td>
</tr>
<tr>
<td>Weight (kgs)</td>
<td>52.1 ± 2.5</td>
</tr>
<tr>
<td>Distance from UCIL Factory (kms)</td>
<td>1.9 ± 0.5</td>
</tr>
</tbody>
</table>
and severe lung restriction was recorded in 0.3% and 0.6% population respectively. Mixed respiratory impairment was recorded in 22.2% of the population studied (Table 6). Its prevalence was significantly higher in the female population ($P<0.05$). Smoking did not make any difference in the prevalence of mixed respiratory impairment. The mild category of mixed respiratory impairment was observed in 14.9% cases. Sexwise, it was the female population which suffered more ($P<0.01$). 4.8% and 2.4% of the study population suffered from moderate and severe types of mixed respiratory impairment (Table 6). Sexwise moderate category was more prevalent in the female cases ($P<0.01$), while severe mixed impairment was equally present in both sexes.

**Discussion**

Various types of pulmonary impairment were recorded in the population exposed to the toxic gas. It was observed that the study population suffered from three types of impairment, viz. obstructive, restrictive and combined. The majority of the population suffered from the mixed type of respiratory impairment.

**Table 3** Prevalence of Respiratory Impairment in Population Classified According to Sex and Smoking habits.

<table>
<thead>
<tr>
<th>Sex and smoking habits</th>
<th>Total</th>
<th>Persons with normal spirometry</th>
<th>Respiratory Impairment</th>
<th>Total impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Persons with obstructive impairment</td>
<td>Persons with restrictive impairment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Male population</td>
<td>371</td>
<td>245</td>
<td>66.0</td>
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<tr>
<td>Non smokers</td>
<td>179</td>
<td>125</td>
<td>69.8</td>
<td>3</td>
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<tr>
<td>Smokers</td>
<td>192</td>
<td>120</td>
<td>62.5</td>
<td>11</td>
</tr>
<tr>
<td>Female population</td>
<td>412</td>
<td>230</td>
<td>55.8</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>783</td>
<td>475</td>
<td>60.6</td>
<td>29</td>
</tr>
</tbody>
</table>

* FEV/FVC% less than 70%  
* FVC less than 80% of the predicted values  
* FVC less than 80% of the predicted value and FEV/FVC ratio less than 70%
impairment followed by the restrictive type. The results indicated that toxic gas inhalation caused a mild form of pulmonary impairment.

Spirometry studies revealed that majority of the pulmonary functions were subnormal. The spirometric parameters, i.e., VC, FVC, FEV₀·₇₅, FEV₁, FEV₁/FVC ratio and IMBC revealed decreased mean, observed values in contrast with their respective reference values.

Thus the present study provides ample evidence of pulmonary hazard in the population exposed to the toxic gas as indicated by the decreased respiratory function values and high prevalence of respiratory impairment. The physiological mechanisms responsible for causing lung impairment induced by toxic gas inhalation are not yet clear. Some investigators believe that isocyanates have an acute irritant effect on the respiratory tract resulting in the bronchospastic reactions, while others, suggest that isocyanate induced respiratory disease may be immunologically mediated. A third hypothesis is that the isocyanates are pharmacologically active and on inhalation may react with components of the lung tissue leading to changes or to the inhibition of biological functions. Two types of pulmonary responses to isocyanate exposure have been suggested. One is the direct irritant response due to triggering of normal protective mechanism of the upper respiratory tract and the second is host generated and truly allergic.

References