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# SEQUENTIAL HEALTH EFFECT STUDY IN RELATION TO AIR POLLUTION IN BOMBAY. INDIA

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**Key words:** Air pollution - Health effects - Epidemiologic study - Lung function.

A health study done for 4 years in 4129 subjects from 3 urban (High, medium and low according to $SO_2$ levels) and a rural community showed a higher morbidity with raised levels. Initially in the respective 4 areas standardised prevalences (in percent) were: for dyspnoea 7.3, 6, 3.2 and 5.5; for chronic cough 5.1, 2.7, 1.7 and 3.3; for intermittent cough 15.6, 5.8, 0.4 and 3.7 and frequent colds 18.0, 20.8, 12.1 and 11 percent. The diagnosis of chronic bronchitis was done in 4.5, 4.5, 2,3 and 5.0 percent and cardiac disorders 6.8, 4.3, 8.2 and 2.7 percent in respective 4 areas.

After 3 years, 55-60% of urban and 44% of rural subjects were reassessed. Several minor symptoms, besides above ones were related closely to the urban air pollutant profile. Increased greenery protected only at lower levels of pollution. Initial lung functions were best in « urban low » area but in all urban areas, yearly declines were larger than in rural subjects.

A cross sectional study for effect of slums in 4 areas on 22272 subjects revealed generally higher morbidity in slum residents, particularly in « urban medium » area for frequent colds, cough and dyspnoea. Daily health diaries maintained in 2232 subjects revealed high morbidity in 2 more polluted areas; monthly trends correlated to $SO_2$ and S.P.M. and daily fluctuations with $SO_2$ revealed a threshold between 50 to 100 μg/C M/day.

There were greater mortality (S.M.R.) in cardiorespiratory and malignant diseases related to pollution. The major factors affecting morbidity were pollution, nutrition, occupation, smoking and age.

## INTRODUCTION

It is wellknown that rapid industrialisation and urbanisation particularly in developing world, there is a general deterioration of environment. In addition to inadequate housing, sanitation, poor water supply and malnutrition, the urban populations have been exposed to rising levels of air pollution.

In Bombay a pilot air monitoring study, of 35 sites identified central zone as the most polluted, eastern suburb as moderately polluted and western suburb as less polluted (3).

While it is common knowledge that acute episodic increase in air pollutants lead to large morbidity and mortality as in London Fog (29), it is more difficult to prove a causal relationship with air pollutants while accounting for the effects of tobacco smoking (12) and above stated interacting factors. In a study of health effects done in California (7, 30) with similar differences in pollutant profile showed that several clinical and functional parameters could be attributed to differences in pollution.

Therefore to clarify the position in India, a prospective study of 3 urban communities in Bombay with different pollutant profiles alongwith a rural control has been done over 6 years at this institute; this paper details its main findings.

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## MATERIALS AND METHODS

The Bombay city is a north-south island about 40 km long and 2-10 km wide. The city has grown steadily over 120 years but faster during last 40 years. From the earlier study (3), it was seen that central zone showed the highest levels of $SO_2$ and S.P.M.. The populations as per 1981 census of central zone was 1.70 million while for eastern and western suburbs it was 2.0 and 1.81 millions respectively. From these three zones, residential colonies of middle three socioeconomic groups were selected for census (excluding migrant and slum dwellers consisting of 20-35%) which was carried out between December 1976 and February 1977. In this, data regarding age, sex, income, smoking habits, occupation and duration of residence was collected. Thus as seen in Table 1, in three respective urban and a rural communities 5092, 2140, 2586 and 2110 subjects were enumerated; only 41, 27, 50 and 4 families in respective localities refused to participate.

Broadly the urban high (Lalbaug) community had an older housing, traffic congestion, several old and new industries while the urban medium (Chembur) community had newer housing surrounded by chemical industries and the urban (low) area had a reasonably good housing in a locality on an arterial road but away from industries. The rural community composed of two agricultural and trading villages situated 40 km south-east of the city with no industry except a small rice mill and minimal traffic.

The monthly family income per unit was derived (male adult: 1.0, female adult: 0.8, Child between 7-12 years: 0.6 and child below 6: 0.4) and was divided as shown in Table 2.

Tobacco smoking was graded as cigarette, bidee smokers, ex-smokers and nonsmokers in males (only 0.4% females were smokers).

The area of residential flat was measured and the family graded for basic characteristics. To reduce interarea differences in census, families were selected from 4 areas on computer as a random matched group. In each group for various age, sex, smoking and residential groups adequate numbers were ensured on the basis of 60% anticipated follow up after 3 years. The number selected with their age groups are listed in Table 1. Over 1977 all these subjects selected were assessed with a medical questionnaire (patterned after BMRC respiratory proforma 1976), history of smoking, residence, work, cooking fuel. Also clinical examination, blood, leucocyte, counts, urine test, 70mm chest radiograph and lung function tests were carried out. Out of total of 4129 index group, 432 voluntary subjects from the same communities, had to be included for ensuring better cooperation. By a separate analysis, these were considered to behave similarly.

The population was followed every 6 months with lung function, cliincal assessment for 3 years. In each area, during the period a greenery index, housing study and nutritional study were carried

TABLE 2.
Socioeconomic characteristics of study population.

| | Urban High | Medium | Low | Rural |
|---|---|---|---|---|
| a) Income/month/per unit % | | | | |
| Mean Family Unit | 4.8 | 4.7 | 4.3 | 5.4 |
| Upto Rs. 200 | 32 | 37 | 10 | 78 |
| Rs. 201-400 | 48 | 44 | 39 | 18 |
| > Rs. 401 | 20 | 10* | 51* | 4* |
| | | * Diff: P<0.01 | | |
| b) Duration of Residence upto 5 years | 11.0 | 20.6 | 16.5 | 17.2 |
| c) Tobacco Smoking (Males) % | | | | |
| Cigarette | 13.2 | 13.3 | 14.7 | 5.6 |
| Bidee | 1.9 | 4.3 | 0.6 | 8.8 |
| Ex-Smoker | 6.3 | 3.2 | 2.4 | 1.2 |
| | Only 0.4% females were smokers | | | |
| d) Housing floor area | | | | |
| Temporary | 1.0 | 0.0 | 0.0 | 39.0* |
| Upto 250 sq. ft. | 8 | 7 | 16 | 29 |
| 251-500 ft. | 10 | 58 | 48 | 21 |
| > 500 ft. | 81** | 33 | 46 | 11 |
| | | * P<0.01 | | |
| | | ** P<0.05 | | |
| e) Cooking flue % | | | | |
| Wood/coal | 21 | 6 | 0.1* | 96* |
| | | | | * P<0.001 |

TABLE 1. — Age-Sex distribution of 4 communities in air pollution study.

| | Census Total | Index Study | No. Male | Female | Age % 1-10 M | 1-10 F | 11-19 M | 11-19 F | 20-44 M | 20-44 F | 45 + M | 45 + F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) Urban High | 5092 | 1008 | 522 | 486 | 21 | 18 | 24 | 25 | 35 | 44 | 20 | 14 |
| 2) Urban Medium | 2140 | 1122 | 586 | 536 | 22 | 26 | 26 | 24 | 33 | 41 | 12 | 9 |
| 3) Urban Low | 2586 | 992 | 468 | 524 | 20 | 23 | 26 | 21 | 30 | 38 | 24 | 18 |
| 4) Rural | 2110 | 1007 | 501 | 506 | 30 | 24 | 30 | 28 | 26 | 33 | 14 | 15 |

out and a majority were persuaded to maintain a daily health diary.

Air pollutants were measured electrochemically using standard methods using a high volume sampler as $SO_2$, S.P.M. and $NO_2$ for 7 weekdays, every month in three urban areas and at every season in rural area. Various data obtained were coded and analysed on computer as multiple two way tables, interrelations, regression analyses. The methodology in greater detail has been reported earlier (22, 23, 28).

## RESULTS

*Basal Characteristics*

Table 1 shows age-sex characteristics of the census and index study population. By matching, interarea differences reduced but still remained significant (e.g. if sex ratioes of 4 census areas varied between 1.02 to 1.22, for index groups the ratioes were 0.89 to 1.09). Similarly age differences though became smaller, persisted with more young subjects in rural area; and more males in the urban high and medium areas.

Table 2 shows socioeconomic characteristics of the study group. The rural family size was larger than in urban areas reflecting the trends for population control in India. The rural and urban incomes are not comparable but certainly the former seemed poorer. So we matched somewhat richer subjects in urban low area with this for adjusting the interarea differences; even after matching the differences remain significant ($P<0.01$).

There were more subjects in urban medium area with shorter residence; the interarea differences reduced but still remained significant ($P<0.01$). There are no interarea differences for tobacco smoking in males (Table 2c) but rural group had more beedi smokers and ex-smokers were more in urban high area ($P<0.01$). Rural subjects were milder smokers.

Table 2d shows that 39% subjects were residing in temporary houses and the flats in urban high area were significantly larger ($P<0.05$). Similarly, fuel used in cooking was wood or coal in 21% of urban high and 96% of rural subjects ($P<0.001$).

More subjects were doing dusty jobs in the two more polluted areas, while rural area had more manual workers. Though matching reduced the interarea differences, these persisted significantly between 4 areas.

*Initial findings*

Table 3(a) lists the percentage of subjects followed yearly. The cause of defaults was mainly noncooperative attitude which became accentuated later. The number of subjects dying over 3 years in respective areas were 19, 10, 2 and 18 in the respective 4 areas ($P<0.05$). The proportions with shift of residence were 31% (rural) and 12 to 17 percent (in 3 urban) respectively.

Lung function tests were not carried out in children below 7 years of age (4-14% of total). About 2-3% refused doing the test initially and this proportion increased upto 16% (rural) in later assessments. Unsatisfactory records due to poor cooperation varied initially from 0.3 to 0.9% in 3 urban and 2.6% in rural areas; later their proportions decreased.

TABLE 3.
Intensity of follow up and mean air pollutant levels during 3 year study period.

| | | Urban High | Medium | Low | Rural |
|---|---|---|---|---|---|
| a) Index Population | | 1008 | 1122 | 992 | 1007 |
| % followed | | | | | |
| | 1 yr. | 75.0 | 61.4 | 70.8 | 46.4 |
| | 2 yr. | 66.9 | 61.0 | 67.7 | 55.6 |
| | 3 yr. | 60.1 | 54.0 | 53.2 | 43.8 |
| b) Mean annual levels in $\mu g/M^3$/day | | | | | |
| $SO_2$ | 1 yr. | 128 | 65 | 28 | — |
| | 2 yr. | 97 | 69 | 35 | 6 |
| | 3 yr. | 90 | 37 | 27 | 7 |
| SPM | 1 yr. | 454 | 341 | 233 | — |
| | 2 yr. | 255 | 222 | 204 | 235 |
| | 3 yr. | 264 | 236 | 231 | 313 |
| $NO_2$ | 1 yr. | 52 | 66 | 38 | — |
| | 2 yr. | 23 | 27 | 18 | 7 |
| | 3 yr. | 25 | 22 | 17 | 6 |

Table 3b lists the annual mean $SO_2$, S.P.M. and $NO_2$ levels for 3 years of study. The levels for $SO_2$ differed significantly in 4 areas ($P<0.01$) but not for S.P.M.. For $NO_2$, all urban areas were similar but rural area had lower levels ($P<0.05$).

Table 4 details the initial clinical abnormalities. The respiratory symptom frequency was standardised for age, sex, smoking and family income. The urban low group showed the lowest ($P<0.05$) while the urban high had the highest prevalence. For paroxysmal and exertional dyspnoea, trends were similar, and both were complained oftener at ages above 45 years. The urban medium subjects had a higher frequency for common colds. For 4 respiratory symptoms, the two more polluted areas showed a high and the rural group intermediate morbidity.

Table 4b shows the ultimate diagnoses reached on each subject. It is seen that chronic bronchitis was least common in urban low area and eosinophilia (under'other Chest') was commoner in rural area ($P<0.05$). Cardiac abnormalities (viz: high blood pressure and ischemia) were commoner in urban low and high areas.

TABLE 4.
Initial clinical prevalence of abnormalities.

| | Urban High | Medium | Low | Rural |
|---|---|---|---|---|
| a) Respiratory | | | | |
| Symptoms % (Standardised) | | | | |
| Breathlessness | 7.3○ | 6.0 | 3.2○ | 5.5 |
| Common colds (8+/yr.) | 18.0 | 20.8+ | 12.1 | 11.0+ |
| Intermitt. cough | 15.6* | 5.8 | 0.4 | 3.7 |
| Chronic cough | 5.1◇ | 2.7 | 1.7 | 3.3 |
| | No sex differences | | | |
| | ○ $P<0.05$ | + $P<0.05$ | | |
| | * $P<0.01$ | ◇ $P<0.01$ | | |
| b) Diagnosis % | | | | |
| Chronic bronchitis | 4.5 | 4.5 | 2.3○ | 5.0 |
| T.B. | 0.4 | 0.2 | 0.1 | 0.2 |
| Other chest | 1.0 | 0.6 | 0.8 | 3.0* |
| Heart | 6.8+ | 4.3 | 8.2+ | 2.7 |
| General disease | 2.8 | 9.1 | 1.9 | 3.4 |
| | ○ $P<0.05$ | + $P<0.05$ | | |
| | * $P<0.05$ | | | |
| c) Minor symptoms % | | | | |
| Skin allergy | 8.8+ | 8.7 | 5.4+ | 0.7+ |
| Stuffy Nose | 19 | 23○ | 12○ | 11○ |
| Chest pain | 7 | 8.6 | 4.9 | 4.9 |
| Eye irritation | 10.1 | 7.2 | 2.0 | 0.6 |
| Headache: Males | 8.4 | 6.1 | 1.9* | 5.0 |
| Females | 16.3 | 13.8 | 5.8 | 13.4 |
| BP > 140/90 | 4.4◇ | 1.8 | 5.9◇ | 1.6 |
| | ○ $P<0.05$ | + $P<0.05$ | | |
| | * $P<0.01$ | ◇ $P<0.05$ | | |

Table 4c shows that nasal complaints were more frequent in two polluted areas as also history of skin allergy and other minor symptoms. Recorded raised blood pressures were, like cardiac diagnostic category, higher in urban high and low areas only.

Table 5 shows standardised lung functions (for age and height) in adults. In children (not tabulated) and adults, rural area shows lowest and urban low area the highest values (MEFR: $P<0.01$; PEF: $P<0.05$); spirometric values are similar in three urban groups. For detecting differences in behaviour of lung function it was shown by intercorrelative analyses that $FEV_1$ and MEFR are more sensitive indices.

Table 6 reveals the effect of greenery on respiratory symptoms (viz: chronic cough and dyspnoea). The former was measured as number of trees taller than 3 meters per acre in each residential clusters (1, 3, 3 and 2) in respective 4 areas. No relation was seen in urban high or medium areas but for urban low and rural areas prevalence of cough and dysponea (but not common colds and intermittent cough) were inversely related to greenery ($P<0.05$).

## *Seasonal variations*

These were studied as seasonal pollutant means with respiratory symptoms. The frequency for dyspnoea was higher for summer in all areas ($P<0.05$) but for cough in urban medium and rural areas, winter was worse ($P<0.05$). For multiple chest symptoms, in urban medium area, summer was worse and in rural area, winter

TABLE 5. — Standardised pulmonary function (Mean ± SD litres) at initial stage in adults.

| Area | Sex | Age | No. | VC-P | FVC | $FEV_1$ | $MEFR_{0.25-0.75}$ | PEF |
|---|---|---|---|---|---|---|---|---|
| High | M | 20-44 | 181 | 3.52 | 3.27±0.60 | 2.80±0.58 | 200±64 | 413±76 |
| | | 45 + | 101 | 3.20 | 2.87±0.58 | 2.30±0.54 | 157±67 | 318±86 |
| | F | 20-44 | 204 | 2.26 | 2.08±0.52 | 1.82±0.45 | 139±50 | 300±68 |
| | | 45 + | 54 | 2.11 | 1.80±0.52 | 1.56±0.44 | 122±52 | 246±35 |
| Medium | M | 20-44 | 187 | 3.45 | 3.27±0.63 | 2.81±0.65 | 216±83 | 445±71 |
| | | 45 + | 106 | 3.25 | 3.07±0.93 | 2.39±0.54 | 169±74 | 416±99 |
| | F | 20-44 | 208 | 2.30 | 2.08±0.44 | 1.86±0.40 | 148±53 | 306±58 |
| | | 45 + | 44 | 2.20 | 1.87±0.52 | 1.77±1.19 | 118±44 | 266±79 |
| Low | M | 20-44 | 142 | 3.53 | 3.18±0.68 | 2.76±0.66 | 214±79 | 472±87 |
| | | 45 + | 109 | 3.14 | 2.65±0.58 | 2.26±0.54 | 161±69 | 414±94 |
| | F | 20-44 | 186 | 2.30 | 2.06±0.39 | 1.84±0.39 | 145±54 | 322±57 |
| | | 45 + | 87 | 2.06 | 1.70±0.40 | 1.51±0.38 | 126±54 | 281±68 |
| Rural | M | 20-44 | 124 | 3.31 | 3.09±0.70 | 2.69±0.64 | 211±87 | 412±94 |
| | | 45 + | 63 | 2.90 | 2.46±0.69 | 1.98±0.60 | 158±83 | 339±68 |
| | F | 20-44 | 148 | 2.22 | 1.96±0.44 | 1.82±0.40 | 155±53 | 275±59 |
| | | 45 + | 64 | 1.95 | 1.45±0.48 | 1.34±0.40 | 116±42 | 236±65 |

Statistical differences in text.

TABLE 6.
Effect of greenery on respiratory symptoms (Trees taller than 3 metres) at 2 year stage.

| Area | | Tree/Acre index. | Chr. Cough % | Dyspnoea % |
|---|---|---|---|---|
| i) High | | 4.26 | 6.1 | 6.4 |
| ii) Medium | a | 7.63 | 2.1 | 5.6 |
| | b | 16.05 | 3.9 | 7.6 |
| | c | 37.23 | 8.9 | 5.1 |
| iii) Low | a | 11.93 | 4.1 | 8.2 |
| | b | 27.24 | 3.2 | 4.0 |
| | c | 30.84 | 1.3 | 3.8 |
| iv) Rural | a | 18.54 | 7.8 | 8.8 |
| | b | 29.0 | 3.4 | 6.8 |

No relation in high and medium area to greenery index but in other two areas higher index had lower morbidity ($P<0.05$).

showed higher prevalences (not tabulated). For smokers winters were worse for chest symptoms but not upper respiratory. For other minor symptoms, trends were conflicting. Generally differences with seasons were small (Bombay has mild seasonal variations), while with pollution levels these were larger.

*Nutritional Study*

From the original index study population, a full diet assessment by recall method as recommended by «Indian Council of Medical Research» was done on two occasions (summer and winter) by home visits. All mean weekly consumptions were tabulated with nutritive values; optimal daily calorie and protein intakes were derived from the

TABLE 8.
Multiple regression with pollution, other factors and clinical respiratory abnormalities in regularly followed subjects for 3 years.

| a) Other factors No. | High 522 | Medium 457 | Low 445 | Rural 246 |
|---|---|---|---|---|
| i) Age | 0.09 | 0.07 | 0.09 | 0.14 |
| ii) Sex | —0.07 | —0.06 | —0.04 | —0.02 |
| iii) Smoking | 0.12 | 0.12 | 0.12 | 0.23 |
| iv) Occupation | —0.12 | —0.08 | —0.09 | —0.15 |
| v) Cooking fuel | 0.02 | 0.02 | 0.11 | 0.07 |
| vi) Housing | 0.04 | 0.01 | 0.03 | 0.01 |
| vii) Duration of Residence | —0.06 | 0.02 | 0.01 | 0.04 |
| viii) Sanitation | 0.002 | 0.02 | 0.02 | 0.05 |
| ix) Nutrition | 0.08 | 0.12 | 0.11 | 0.14 |

| b) Pollutants | All urban areas. | | | | | |
|---|---|---|---|---|---|---|
| | $SO_2$ | | S.P.M. | | $NO_2$ | |
| | Initial (0) | 3 yr. | 0 | 3 yr. | 0 | 3 yr |
| Frequent common colds | 0.03 | 0.13 | 0.20 | 0.12 | 0.40 | 0.30 |
| Intermitt. cough | 0.17 | — | 0.36 | — | 0.31 | — |
| Cough + Sputum | 0.72 | 0.38 | 0.57 | 0.16 | 0.59 | 0.61 |
| Breathlessness: | 0.78 | 0.09 | 0.66 | 0.66 | 0.70 | 0.08 |
| Chronic attacks | 0.29 | — | 0.45 | — | — | — |
| Multiple chest symptoms | — | 0.43 | — | 0.30 | — | 0.31 |

TABLE 7. — Nutritional analyses and correlation with clinical abnormalities.

| No. studied (%) | High 635 (63) | | Medium 705 (63) | | Low 617 (62) | | Rural 758 (75) | |
|---|---|---|---|---|---|---|---|---|
| Mean calorie ± SD | 1772±488 | | 1509±438 | | 1659±414 | | 1363±406 | |
| Mean Protein gm. ± SD | 48±16 | | 43±14 | | 43±14 | | 32±12 | |
| a) Nutrition groups % | M | F | M | F | M | F | M | F |
| i) inadequate protein (<30gm) & calorie (<80%) | 5 | 10 | 7 | 17 | 4 | 11 | 32 | 32 |
| ii) adequate protein inadequate cal. | 43 | 34 | 43 | 33 | 48 | 41 | 28 | 18 |
| iii) Adequate calorie (<30gm) Poor Protein | 2 | 5 | 5 | 3 | 3 | 6 | 12 | 1 |
| iv) Adequate Cal. + Protein | 50 | 51 | 46 | 43 | 45 | 42 | 28 | 33 |
| b) Clinical abnormalities % | | | | | | | | |
| i) Inadequate Cal. & Prot. | 38* | | 31 | | 13 | | 18 | |
| ii) Inadequate Cal. only | 33 | | 30 | | 10 | | 7 | |
| iii) Inadequate Prot. only | 23 | | 28 | | 21 | | 23 | |
| iv) Adequate (both) | 28 | | 27 | | 15 | | 15 | |

* $P<0.05$.

ICMR report (details as in Ref. 28). For analysing morbidity relationship the groups were: i) for calories below 50, 51-80 and above 80 percent of predicted; ii) for protein - below 30 gm and above. The heatlh morbidity was categorised as normal, frequent common colds, dyspnoea or cough alone and multiple chest symptoms.

The caloric intake was consistently but slightly higher in summer. The relationship to monthly income was also strong. The urban high area had the highest intake of food while the rural was the lowest; $P<0.001$ (Table 7). Females oftener had a low protein intake in all 4 areas ($P<0.02$). Clinical abnormalities were grouped as dyspnoea, colds and multiple chest symptoms.

In urban high area, there is significant relationship with poor caloric intake and morbidity ($P<0.05$). The difference for « low » area is significant in some categories only.

*Third year analyses*

Analyses on only the group of regularly followed (for all 3 years) subjects (Table 8), were done to evaluate the role of other interacting factors. The defaulting groups in urban areas, had a higher prevalence of dyspnoea and abnormal diagnoses in all 3 years but cough only occasionally, was seen oftener. For frequent colds in the urban high and medium groups defaulters were worse (not tabulated).

Among the respective 4 areas regular drug intake was recorded in 7.5, 11.0, 6.3 and 2.4 percent subjects ($P<0.05$).

Table 8 lists intercorrelations with various factors in the regular groups of subjects for each area, in regard to chest symptoms (grouped as asymptomatic, only frequent colds, only cough, only dyspnoea and multiple). It is seen that the correlation was closer for occupation, smoking and age (particularly in rural area). In contrast, the correlations for 3 pollutants worked out on the initially studied and third year (regular) population, are strong and significant. Thus frequent colds are more related to $NO_2$, intermittent cough to S.P.M., productive cough to all three pollutants, dyspnoea more to S.P.M. and multiple chest symptoms more to $SO_2$.

Table 9 lists analyses for lung function trends. We have assumed that declining trends may not be evident in all age groups or areas: so far FVC and $FEV_1$ analyses are presented for many subdivisions.

TABLE 9. — Yearly lung function trends in regular study populations over 3 years.

| | High | | Medium | | Low | | Rural | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| a) FVC ml. | | | | | | | | |
| all adults | — 52 | —100 | —123 | —127 | —116 | —170 | + 28 | + 74 |
| 15-19 yr. | — 20 | — 10 | — 6 | — 76 | — 9 | — 48 | + 68 | + 50 |
| 20-25 | — 92 | — 38 | — 97 | — 63 | — 48 | — 99 | + 50 | — 61 |
| 26-30 | —108 | — 73 | —170 | — 68 | —182 | — 85 | — 39 | — 74 |
| 31-40 | —143 | — 21 | — 87 | —120 | —147 | +106 | —148 | — 50 |
| 41-44 | —142 | — 43 | —175 | —114 | —192 | — 85 | —204 | — 26 |
| 45-50 | —140 | — 87 | —141 | —104 | —131 | — 90 | — 18 | + 15 |
| 51-55 | —201 | —100 | — 94 | — 45 | —107 | — 55 | —129 | — 72 |
| > 55 | +172 | — 32 | —176 | —205 | —182 | — 92 | —173 | — 58 |
| b) $FEV_1$ ml. | | | | | | | | |
| all adults | — 29 | — 29 | — 62 | —201 | —383 | —319 | — 27 | — 21 |
| 15-19 yr. | + 39 | + 22 | + 19 | — 43 | + 19 | — 30 | + 84 | + 45 |
| 20-25 | — 42 | — 20 | — 7 | — 13 | — 59 | — 56 | — 27 | — 20 |
| 26-30 | — 14 | — 61 | — 65 | — 3 | —136 | — 41 | + 49 | — 53 |
| 31-40 | — 34 | + 11 | — 59 | — 91 | — 45 | — 58 | — 23 | — 36 |
| 41-44 | — 70 | — 8 | — 92 | — 52 | — 95 | — 60 | —123 | — 58 |
| 45-50 | — 65 | — 41 | — 49 | — 89 | — 85 | — 80 | + 29 | + 29 |
| 51-55 | —111 | — 84 | — 71 | — 4 | — 80 | — 91 | + 29 | — 35 |
| > 55 | + 92 | — 8 | — 89 | — 17 | —105 | — 60 | —108 | — 63 |
| c) Proportion: low (<80%) $FEV_1$/FVC% | 26.7 | 14.7 | 16.5 | 10.6 | 16.4 | 10.6 | 11.5 | 4.3 |
| d) PEF lit. all adults | +12.2 | +25.5 | —7.1 | —20.7 | —33.3 | 29.0 | — 22.9 | —25.2 |
| e) $MEFR_{0.25-0.75}$ Lit all adults | —14.5 | +29.0 | +12.1 | — 3.6 | —36.9 | —29.9 | +10.4 | +40.7 |

TABLE 10. — Seasonal variation in health morbidity in relation to air pollution over 2 years.

| Urban | High | | Medium | | Low | | Rural | |
|---|---|---|---|---|---|---|---|---|
| No. | 569 | | 464 | | 488 | | 255 | |
| a) Health morbidity: | Winter | Summer | W | S | W | S | W | S |
| i) Colds 8+/yr. + Productive cough + Dyspnoea. | 10.9 | 9.8 | 14.6 | 16.2 | 11.7 | 11.4 | 10.0 | 8.6 |
| ii) Prod. cough + Colds 8+/yr. | 2.5 | 3.6 | 2.9 | 2.6 | 1.7 | 1.5 | 3.1 | 2.0 |
| iii) Intermitt. cough | 4.7 | 7.7 | 5.2 | 7.0 | 4.0 | 3.0 | 2.7 | 6.5 |
| iv) Dyspnoea only | 2.4 | 1.8 | 2.4 | 1.7 | 1.1 | 0.9 | 3.3 | 3.5 |
| v) Total | 22.5 | 22.9 | 25.1 | 27.5 | 18.5 | 16.8 | 19.1 | 20.6 |

No significant differences.

b) Weather data:

| | | High (South Bombay) | | Low (Western Suburb) | |
|---|---|---|---|---|---|
| | | Temp. diff. | Humidity | Temp. diff. | Humidity |
| Summer (April) | 1977 | 7.1 ± 0.7 | 74.0 ± 6.2 | 7.9 ± 1.2 | 70.5 ± 4.9 |
| | 1978 | 7.0 ± 1.5 | 76.4 ± 5.7 | 9.2 ± 2.5 | 68.7 ± 15.0 |
| | 1979 | 7.8 ± 1.0 | 78.3 ± 3.9 | 9.9 ± 2.6 | 74.8 ± 7.5 |
| | 1980 | 7.3 ± 0.8 | 77.0 ± 4.6 | 8.4 ± 1.8 | 73.4 ± 7.8 |
| Winter (Jan.) | 1977 | 10.9 ± 2.5 | 74.3 ± 11.9 | 13.6 ± 2.7 | 62.2 ± 16.9 |
| | 1978 | 9.9 ± 1.7 | 71.2 ± 10.5 | 14.2 ± 3.0 | 65.8 ± 11.7 |
| | 1979 | 9.5 ± 1.5 | 79.1 ± 9.5 | 12.1 ± 1.7 | 71.9 ± 10.8 |
| | 1980 | 10.5 ± 1.4 | 80.2 ± 8.1 | 11.4 ± 1.8 | 71.2 ± 8.1 |
| Monsoon (Aug.) | 1977 | 5.4 ± 0.9 | 85.8 ± 4.6 | 4.6 ± 0.9 | 86.1 ± 5.3 |
| | 1978 | 4.4 ± 1.1 | 86.0 ± 3.5 | 4.6 ± 0.6 | 86.7 ± 5.0 |
| | 1979 | 4.6 ± 1.1 | 87.8 ± 5.8 | 6.9 ± 1.3 | 85.6 ± 6.6 |
| | 1980 | 6.1 ± 1.5 | 89.2 ± 5.7 | 7.6 ± 2.2 | 89.7 ± 6.5 |

Daily maximum temp. varies between 29 to 36°C. Humidity is significantly higher in monsoon and lowest in winter. Southern city has smaller temperature differences.

c) Seasonal pollutant levels:

| | High | | | Medium | | | Low | | | Rural | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean ± SD | $SO_2$ | SPM | $NO_2$ | $SO_2$ | SPM | $NO_2$ | $SO_2$ | SPM | $NO_2$ | $SO_2$ | SPM | $NO_2$ |
| Winter | 139.1 ± 54.1 | 286 ± 81 | 37.1 ± 18.2 | 63.0 ± 30.6 | 177 ± 76 | 19.8 ± 10.1 | 60.3 ± 23.3 | 282 ± 43 | 33 ± 10.3 | 8.2 ± 5.3 | 267 ± 79 | 4.7 ± 2.1 |
| Summer | 89.9 ± 22.4 | 259 ± 106 | 18.3 ± 16.8 | 37.0 ± 22 | 185 ± 56 | 11.0 ± 6.8 | 25.7 ± 18.2 | 246 ± 69 | 16.3 ± 13.7 | 6.3 ± 3.1 | 239 ± 29 | 7.3 ± 4.6 |
| Monsoon | 114.5 ± 54 | 199 ± 93 | 7.9 ± 4.3 | 66.2 ± 61.0 | 223 ± 127 | 8.9 ± 5.7 | 23.3 ± 19.1 | 174 ± 45 | 14 ± 8.8 | 8.8 ± 4.0 | 130 ± 18 | 2.3 ± 0.2 |

The trends in total adults in 4 areas were not significantly related to pollutant levels. The rate of increase in function at 5 to 19 year age was higher for rural subjects. The urban subjects (particularly females) have started showing a decline in FVC at 15-19 year age group. Generally between 20 to 40 years declines were smaller in rural subjects of both sexes and urban males showed larger declines. At older ages, declines were large in all urban areas. So, rural subjects, though showing lower functions initially (Table 5), preserved these better at older ages. At all observed levels of pollution range, urban subjects showed significantly enhanced declines. The trends were similar for all 4 tests and no additional information could be obtained by age-wise splitting of expiratory flow rates.

*Seasonal factors*

For this analysis from the study population, those followed on 2 successive winters and summers were included (Table 10). Thus 569, 464, 488 and 255 subjects qualified for this assessment. Table 10 lists the mean respiratory symptom morbidity for 2 seasons divided into 4 categories alongwith a total. In rural area, adults were worse for dyspnoea in summer as also for cough the urban high area in children ($P<0.05$ for both). In urban medium and rural area for cough, summer was worse in adults ($P<0.05$). For multiple symptoms, for urban areas summer was worse for « urban medium » area but winter was worse in rural area ($P<0.05$). On all other counts, interseasonal differences were insignificant.

Table 10b gives the weather data for 4 years of study period as differences in temperature (maximum and minimum of the day) as mean monthly reading with SD and mean humidity of the typical month for each of 3 seasons. Generally the maximum temperature over 12 months, varied between 29 to 36°C and minimum fluctuated more in winter (upto 12°C).

Table 10c shows the seasonal mean pollutant levels for first year of study (Table 3 gives yearly means for 3 years). While there are large fluctuations in all urban areas, winter readings for $SO_2$ and $NO_2$ tend to be higher.

Thus the health morbidity (also studied by other parameters) did not correspond to seasonal differences.

*Daily health diary results*

From the index study group we selected 2232 cooperative subjects to maintain daily diary of respiratory symptoms, and medical treatment. Even in 3rd year, 1338 continued to record it regularly (Table 11). We restricted analyses of daily records to those who were at least 75% regular during a year. We also checked on the entries by twice monthly visits. The accuracy was rechecked in third year by weekly visits on 200 subjects in each urban area and the records were found to be reliable.

TABLE 11.
Daily health morbidity in relation to seasons.

| No. studied | Urban High | Medium | Low | Rural |
|---|---|---|---|---|
| 1st year | 710 | 800 | 596 | 126 |
| 2nd year | 623 | 524 | 342 | 103 |
| 3rd year | 445 | 465 | 328 | 100 |
| Symptoms 1st yr. % | | | | |
| a) Monsoon (July) | | | | |
| Colds | 24.8 | 39 | 24 | 2 |
| Cough | 19 | 46 | 7 | 4 |
| Dyspnoea | 6 | 8 | 1 | 1 |
| Medical treatment | 32 | 63 | 8 | 2 |
| b) Winter (Dec.) | | | | |
| Colds | 18 | 53 | 23 | 11 |
| Cough | 13 | 42 | 17 | 2 |
| Dyspnoea | 3 | 5 | 3 | 2 |
| Medical treatment | 24 | 57 | 17 | 2 |
| c) Summer (April) | | | | |
| Colds | 21 | 39 | 13 | 2 |
| Cough | 13 | 29 | 9 | 1 |
| Dyspnoea | 3 | 5 | 3 | 1 |
| Medical treatment | 26 | 36 | 7 | 2 |

(for explanation see text).

Table 11 details typical frequencies for one month in each seasons, of 1st year. Thus it is seen that the « urban medium » area was worst and the « high » area suffered in frequency next. The rural area showed the lowest prevalences and the « low » area was intermediate; it had a low prevalence for dyspnoea and cough, particularly in monsoon and summer. Over next 2 years, (not tabulated) though individual figures varied a little, the trends for differences were similar. When monthly pollution ($SO_2$, S.P.M.) levels were plotted against monthly morbidities, there was evidence that while cough and common colds related to fluctuations in S.P.M., the relation to $SO_2$ was not as clear. The prevalences of dyspnoea did not relate to either pollutants.

Table 12 relates the prevalences for 4 categories of daily respiratory symptoms on 2 days around a monitoring day in regular urban subjects. As the trends are similar for remaining 2 years, table 12 lists the data for 1st year only. For 3 years in 3 urban areas, between low and high $SO_2$ groups 4 morbidities, together correlated well with $SO_2$ levels ($P<0.001$). The threshold for $SO_2$ in the «high» area appeared to be 100 µg and in the medium area 50 µg. In low area, there were no trends as readings above 100 µg were fewer.

*Ancillary studies*

*Slum factor:* In order to assess differences between slum residents and other citizens, we did a cross sectional study in same 4 areas an adjoining communities over 2 years (1980-81). (Table

TABLE 12.
Relation of daily $SO_2$ levels and daily health morbidity of 1st year in 3 urban areas.

| | | High | Medium | Low |
|---|---|---|---|---|
| a) Colds | | | | |
| $SO_2$ | 0-50 | 0.1 | 3.6* | 3.0 |
| µg/M³ | 51-100 | 3.0 | 9.1 | 1.5 |
| | > 100 | 19.2⁺ | 10.3 | 1.5 |
| b) Intermitt. cough | | | | |
| | 0-50 | 0.3 | 3.4* | 1.6 |
| | 51-100 | 1.6 | 7.4 | 1.9 |
| | > 100 | 14.7⁺ | 7.4 | 0.9 |
| c) Chronic cough | | | | |
| | 0-50 | 0.1 | 4.3* | 1.1 |
| | 51-100 | 2.3 | 8.6 | 0.9 |
| | > 100 | 12.0⁺ | 9.9 | 0.9 |
| d) Dyspnoea | | | | |
| | 0-50 | 0.1 | 0.2* | 0.2 |
| | 51-100 | 0.2 | 0.4 | 0.1 |
| | > 100 | 2.1⁺ | 0.8 | 0.1 |

* Threshold below 50 µg $SO_2$.
⁺ Threshold below 100 µg $SO_2$.

13). Though standards of housing in Bombay are generally unsatisfactory, the slums consisted of mud floors, temporary walls and tin roofs. The subjects were included after a full census of identified clusters (only 5-7% were missed). There were fewer older subjects (above age 44 years) in 3 urban areas (P<0.05) and fewer males in rural area.

The slums in 3 urban areas were simliar but that in the low area had slightly higher income. All slum subjects lived in much smaller housing area and had lower incomes. The incomes in rural area, though not comparable were similar to urban slums. The prevalence of tobacco smoking was similar to that in earlier studies. The slum subjects had fewer students and more subjects doing dusty or manual jobs.

The prevalence of diarrhoea (at least 3 motions daily) was higher in all urban areas (P<0.05) and was worse in the « urban medium » slum (P<0.01). For dyspnoea and common colds also subjects from the latter area were worst (P<0.01). For cough, the interarea and slum/residential differences were insignificant. For common colds, the rural area was significantly better (P<0.01). The prevalence of raised (above 140/90mmHg) blood pressure was lower in slums (P<0.01).

TABLE 14.
Standardised mortality rates per lakh population in Bombay.

| City Zone: | South | Central | West Suburbs | East Suburbs |
|---|---|---|---|---|
| i) Population in million: | | | | |
| 1971 | 15.83 | 14.87 | 17.06 | 11.95 |
| 1979 | 16.85 | 17.14 | 17.97 | 19.15 |
| ii) Cardiac: | | | | |
| 1971 | 159.6 | 103.2 | 91.3 | 52.8 |
| 1975 | 132.9 | 109.8 | 120.3 | 57.9 |
| 1979 | 118.5 | 144.1 | 189.4 | 75.9 |
| iii) Respiratory: | | | | |
| 1971 | 254.4 | 288.8 | 217.5 | 299.2 |
| 1975 | 248.0 | 303.0 | 288.0 | 268.0 |
| 1979 | 200.6 | 275.8 | 305.1 | 235.6 |
| iv) Cancer: | | | | |
| 1971 | 64.2 | 40.6 | 44.2 | 22.1 |
| 1975 | 43.0 | 50.8 | 76.2 | 28.6 |
| 1979 | 35.6 | 57.8 | 70.5 | 37.2 |
| BaP μg/ 1000 $M^3$ (1973) | 3.9 | 173 | 5.6 | 1.0 |

*Death cause study*

For evaluating the effect on health morbidity, we extracted causes of death as certified in civic death certificates from 1971 to 1979. For background, only age, sex and area of residence could be clearly mentioned. The causes were divided into tuberculosis or sequelae, other respiratory, gastrointestinal, cardiovascular, infections, cancer and miscellaneous. The city was divided into 4 zones as listed in Table 14. The population as estimated from censuses of 1971 and 1981 is listed as Table 14(i). The mortality rates were standardised for central zone in other areas by age and sex.

The crude death rates revealed that deaths due to infectious diseases for the city declined from 44.1 to 33.6 per 100,000 population over 9 years. Those in miscellaneous causes (mainly trauma) increased from 415.6 to 516.6 over this period. Table 14 lists three categories of deaths as standardised mortality rates. As many certified

TABLE 13. — Effects of slums: cross sectional study.

| | Urban High | | Medium | | Low | | Rural |
|---|---|---|---|---|---|---|---|
| | Resident | Slum | R | S | R | S | |
| No. | 4624 | 579 | 7888 | 1347 | 4273 | 427 | 3124 |
| a) Socioeconomic data | | | | | | | |
| i) Smokers (Male) | 17.8 | 17.6 | 16.7 | 24.4 | 17.3 | 30.7 | 15.8 |
| Ex-smokers | 2.8 | 1.2 | 2.3 | 1.4 | 2.0 | 0.8 | 0.7 |
| ii) Housing area upto 250 sq. ft. | 0 | 94 | 0 | 100 | 37 | 100 | 15 |
| iii) Monthly income low | 36 | 74 | 19 | 78 | 28 | 34 | 84 |
| b) Clinical symptoms: | | | | | | | |
| Diarrhoea | 12.6 | 12.2 | 8.6* | 13.6* | 9.1 | 11.7 | 5.6+ |
| Breathlessness | 10.0 | 3.7 | 3.8◇ | 22.4◇ | 4.2 | 3.0 | 3.4 |
| Cough | 29.4 | 28.8 | 39.3 | 45.2 | 30.6 | 30.4 | 22.5 |
| Frequent colds | 26.9 | 33.1 | 23.8 | 46.6 | 20.9 | 34.7 | 12.2^ |
| High B.P. | 11.2 | 2.7 | 8.6 | 5.1 | 6.8 | 2.6 | 7.8 |

All values in percent.

◇ P<0.01 * P<0.05, +,^ Urban/Rural: P<0.05.

as tuberculosis were due to old tuberculosis or falsely diagnosed, we have included these under respiratory group. The rates for cardiac causes increased over the period under study particularly in urban high (central) and low (western suburb) areas. The latter area has a larger proportion belonging to high income group doing sedentary jobs.

The rates for respiratory causes are stable and high in three zones under study. The rates for cancer are increasing in three zones over 9 years; the trends correspond to high levels of benzopyrene measured (lower for both in eastern suburb zone).

*Vehicle pollution component*

According to estimated pollutant load over the study period approximately 1500 metric tone were being liberated daily in Bombay city. Of this at least half was being contributed by automobile component (1). As we found deaths due to cardiac and malignant causes high in the « urban low » area where industries are few but vehicle congestion is large, we decided to study this factor at a crowded traffic junction in Central Bombay, in 1982. The function chosen has a north-south arterial road with a flyover and a traffic signal at southern end, a branch road which carries 40% traffic and a side lane with little traffic. From these 4 zones subjects of all ages and both sexes were studied with respiratory questionnaire and blood COHb estimation. We earlier studied 20 nonsmoker normals who showed 1.15(±0.26)% COHb reading. Of the subjects studied. only 29, 32, 9 and 29 were smokers. Of these 24, 47, 56 and 31 percent respectively had COHb readings above 3%, while only 24, 3, 8 and 31 percent showed readings in normal (upto 1.5%) range (Table 15). Among nonsmokers, there were greater proportions in the latter range; but in both groups trends in COHb corresponded to the vehicle density for the zone. Thus higher levels of COHb were seen in slow traffic with heavy or moderate vehicle density ($P<0.01$). Those staying in flats facing the road traffic showed a higher COHb level ($P<0.01$). Table 15 also details symptom morbidity, showing that chest pain and irritability was related to vehicle congestion in the above 2 areas.

TABLE 15.
Distribution of Blood CO levels and clinical symptoms at a traffic junction in Central Bombay.

| 1) Traffic Density | Side Lane (Low) | Branch Rd (moderate slow) | South end (Heavy slow) | North end (Heavy fast) |
|---|---|---|---|---|
| 2) No. of subjects | | | | |
| Total | 238 | 231 | 93 | 218 |
| Non-smokers No. | 209 | 199 | 84 | 189 |
| 3) Non-smokers % | | | | |
| CoHb upto 1.5% | 50 | 11 | 8 | 51 |
| >3% | 7* | 22+ | 17+ | 2* |
| Smokers % | | | | |
| CoHb > 3% | 24* | 47+ | 56+ | 31* |
| Upto 1.5% | 24 | 3 | 8 | 31 |
| | | | +,* - P<0.01 | |
| 4) Clinical Symptoms | | | | |
| Cough | 52.5 | 54.2 | 53.7 | 62.4 |
| Dyspnoea | 17.3 | 16.5 | 19.3 | 13.3 |
| Frequent colds (8+/yr) | 32.9 | 30.0 | 29.0 | 23.4 |
| Chest pain | 2.5 | 10.8* | 5.4 | 6.9 |
| Irritability | 0.8 | 2.6 | 10.8* | 2.7 |
| Headache | 16.5 | 33 | 17.2 | 25.2 |
| | | | +,* - P<0.01 | |

## DISCUSSION

Our results show that the « urban low » area had the lowest morbidity except for cardiovascular diseases and deaths due to cancer. The moderately polluted urban area had somewhat higher morbidity for common colds, intermittent cough and dyspnoea. This is different from western studies where rural areas showed the lowest morbidity (14, 27). But we studied villages which had, no sanitation, no protected water supply, poor housing, widespread use of hazardous cooking fuel, poor nutrition contributed by intestinal parasitism, and also poorer medical care. These factors over a long period may explain their poorer health and lung function. However the rural group maintained their function better at older ages indicating the effect of pollutants in urban subjects.

Earlier attempts to correlate health morbidity to air pollutants were complicated by interacting factors particularly tobacco smoking (12, 14, 17). Thus Cohen et al. (6) could not correlate oxidant levels with clinical or functional status. But Ferris et al. (14, 15) showed that lung function declined less when $SO_2$ levels dropped below 35 $\mu g/M^3$ In their study on 9280 children from 6 cities (17, 32) (where in adults there was interaction with smoking) the lung function was not related to socioeconomic status but to parental smoking and cooking fuel.

Ellison and Waller (11) have reviewed the health relationship to $SO_2$ and S.P.M. pollution. They identified main sources as burning of coal, fuel oil and autoexhaust and pointed that due to turbulent air movements the migration of pollutants outside urban areas is poor. This may explain obtaining only background pollution levels in our rural area situated only 40 km away. They also point out that as episodes of extreme rise in pollution having become infrequent, such studies of heatlh effects (18) may not have the same relevance to studies of our type. While air pollution is supposed to interact with weather extremes (4), as our city's pattern is not so variable, it is not surprising that we have found the seasonal factor not as significant.

Aubry et al. (1) studied 3 Canadian communities with similar age, demographic features and differences for $SO_2$ pollution. They could not demonstrate morbidity differences between high and moderately polluted zones. The functional differences seemed restricted to few parameters ($FEV_1$/FVC% higher in females); a significant respiratory effect was demonstrated at $SO_2$ levels of 59 µg or above (1).

Rokaw, Detels et al. (7, 30) studied 3 Californian communities with predominently oxidant, $SO_2$ and minimal pollution levels. There was evidence of lower spirometric and expiratory flow indices with higher $SO_2$ levels; with higher oxidant levels a higher airway resistance and lower flow rates were seen. The differences in smokers, were greater.

Love et al. (26) reported higher prevalences of acute respiratory illness in children residing in a highly polluted area (attributable to $NO_2$ and S.P.M.) when the particular source industry went on strike, there was 47 to 64% reduction in upper respiratory illnesses. This suggested a relationship of these illnesses to pollution. We have found in our analyses that the frequency of common colds was closely linked to daily $NO_2$ levels. The frequency of acute monthly colds declined when pollution levels (particularly $SO_2$) decreased in the « urban medium » and « high » areas due to change of industrial fuel and strike respectively.

Sulphur oxides may act by reducing resistance to bacterial lung infections (19), promoting airway hyperreactivity (35) or by impairing mucociliary clearance through formation of sulphate (25) in presence of high humidity and particulate levels prevailing in Bombay).

Chapman et al. (5) have studied 4 Utah communities with different levels of $SO_2$ pollution with similar methodology over 12 years. They found a significant relationship of chest symptoms to age (more in males), smoking and occupation in addition to $SO_2$ levels.

In our study results, we have found younger children (below 5 years) and older subjects having more respiratory morbidity. This was confirmed by others (2, 12, 31, 32). Recently Dodge et al. (8) have shown that while children chronically exposed to $SO_2$ and S.P.M. develop cough oftener but do not have delayed growth or reduced lung function.

Earlier CHESS studies (12) have also shown an excess prevalence of bronchitis which is enhanced by smoking. Their studies suggested an increase in respiratory infections, dyspnoeic episode, and an effect on lung function with $SO_2$ levels around 95 µg/M³ and S.P.M. levels around 70-100 µg/M³.

Spivy and Radford (33) have shown that due to poorer housing, children suffered more infections and grew inadequately. The factor of indoor pollution (2, 31) which may not be as important in our flats as these have open ventilation, would have more importance in slums as these use a poorer fuel for cooking and have a crowded ventilation. This may be the explanation of our subjects having a greater respiratory morbidity.

We found that by daily health records, the frequency of respiratory symptoms was related to $SO_2$ and S.P.M. levels. Earlier Douglas & Waller (9) had found that frequency and severity of lower respiratory infections to be related to air pollution. In another study in U.S.A. this was found to be true but alongwith climatic factors (4).

More detailed studies in U.S.A. done on students (10, 20) showed a higher frequency of respiratory symptoms on days with higher pollution. Thus Durham (10) showed an increase of 16.7%, in prevalence of colds, sore throat and bronchitis and Hammer et al. (20) found that eye irritation, chest discomfort and cough were related to ozone. We found that with $SO_2$ above 50 to 100 µg/M³, there was an increase in common colds, intermittent cough, chronic cough and dyspnoea.

We also found a higher respiratory, cardiac and cancer mortality associated with higher air pollution. Similar correlation has been found by Winkelstein et al. (36) and Koshal (24) and Epstein & Swartz (13).

Our studies for relating COHb to symptom morbidity found only chest pain and irritability occurring oftener. In areas with more traffic idling, higher COHb levels in subjects were detected. Similar differences in COHb in smokers and industrial zone have been reported by Kahn et al. (21). Tollerud et al. (34) studied 175 tunnel workers and found cough, sputum to be related to tobacco smoking but none of chest symptoms or illnesses or lung functions were related to autoexhaust.

In conclusion, our data from studies done over 1977-82, in Bombay reveal a large cardiorespiratory morbidity and mortality attributable to the prevailing air pollution levels.

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