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Perceived Indoor Quality of Air in Calcutta Proper and Its Relationship to Types of Fuels Used for Cooking

Bishwa Nath Mukherjee
Institute of Health and Environment Management, Calcutta 700 004, West Bengal, India

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ABSTRACT The paper reports the results pertaining to perception of indoor air pollution as experienced by 1,724 residents selected randomly from 56 localities of Calcutta Municipal Corporation. The findings clearly indicate that households mainly using coal ovens and/or kerosene stoves tend to experience greater percentages of inconvenience caused by smoky rooms than households using gas or electric heaters. Indoor air quality was perceived as quite bad by slum dwellers who were reported to be using mostly coal ovens. No association was found between index of indoor air quality and number of sick persons in the household. Almost the same result emerged for number of asthma patients. Although the health hazard of indoor air pollution is not clearly borne out of the study, the results support the need for ventilation improvement for users of coal ovens in kitchen. Indoor cigarette smoking was also found to have almost no association either with indoor air pollution or with any health problems. Some of the implications of the findings are discussed.

There are numerous studies on behavioral aspects of outdoor pollution, a review of which appears in Evans and Jacobs (1981). Yet, very few published studies could be located in the area of people's awareness and perception of indoor air quality. However, quite a few studies indicate that the air within homes and other buildings can be as seriously polluted as the outdoor air in any city. Indoor pollution sources such as kerosene oil, cooking gas and coal ovens release gases or particles into the air. These pollutants are the primary causes of indoor air quality problems in homes. In a rural household survey conducted by NCAER (1981), a little over 35 per cent of the respondents complained of smoking kitchens and eye problems related to smoke. A little over 11% complained of breathing problems as well. A higher prevalence rate of chronic bronchitis has been noted by Pandey (1984) even among nonsmokers in certain regions of Nepal who cook than among those who do not, indicating domestic stove smoke as a possible etiologic factor. The prevalence of chronic bronchitis was nearly equal in men and women inspite of the higher smoking rates among men. The result was explained in terms of the increased time women generally spend in smoke rooms while cooking.

Mohan et al. (1992) recently reported a study on the physical assessment of indoor air quality at selected locations in Pune city. They found that while the sulphar dioxide (SO_2) and nitrogen oxides (NO_x) concentrations were within the permissible limits of ambient air standards, the respirable fraction of the suspended particulate matter (RSPM) which may be carcinogenic was beyond the permissible limits at most of the sampling sides. In other studies, household smoking from domestic coal consumption, firewood, dung and other cooking fuels has been found to be a substantial contributor to personal exposures to undifferentiated respirable size particles (RSP). The most common harmful compounds found in indoor air pollution include Nitrogen Dioxide, Carbon Monoxide, Formaldehyde, Asbestos and various solvents. Earth rock

beneath the house, well water and building materials may also give rise to Radon, another polluant which may be related to lung cancer. The major sources of domestic air pollution in India are biomass, combustion and use of kerosene lamp and stove for lighting and cooking purposes. These often result in high concentrations of Carbon Monoxides in kitchen and high exposure to total suspended articulates (TSP) by household cooks (Ahuja and Joshi, 1986; Ramakrishna, 1987).

Indoor pollution from smoke fires in poorly ventilated huts in the highlands of Papua New Guinea has been found to be "the major and most preventable factor" underline the prevalence of chronic nontubercular lung disease (Ahuja, 1985). Padmavati and Arora (1976) also came to the conclusion that domestic air pollution is the cause of chronic cor pulmonale (a disease of the cardio-respiratory system) in women and its onset at younger ages. A study conducted by the National Institute of Occupational Health, Ahmedabad found a statistically significant association between cooking with smoky fuels and the incidence of cough, dyspoenea and respiratory diseases (NIOH, 1980). Application of the results of occupational epidemiological studies in the United States to indoor exposures, either directly or using recent advances in lung dosimetry, suggests that the average indoor concentration entails a lifetime risk of lung cancer of about 0.4%, contributiong about 10% of the total risk of lung cancer from radon decay products (Nero, 1988).

Since people normally spend most of their time at home, their risk to health may be greater because of exposure to indoor rather than outdoor air pollution. This is especially true for housewives, children and older people. Indoor air pollution now is gaining the serious attention it deserves in the health community.

Although indoor air quality (IAQ) contains hundreds of chemical components, a majority of the indoor air contaminants in public buildings are odorous (Burglund et al., 1982). From the detection of odour which generally gives rise to some kind of discomfort and annoyance, one can easily indicate the malfunction of the ventilation system and contamination of indoor air quality. When indoor air quality is contaminated by smoke from coal oven and kerosene stoves as well as by cigarette smoking, some assessment of indoor air quality can be done just by visual inspection and odour detection. Since the odour of the indoor can not be predicted easily from the chemical composition of the air, sensory analysis especially based on olfactory evaluation (smell sensation) has been used by a large group of Swedish researches (Lindvall, 1970; Burgland et al., 1984) in the studies of indoor air quality. Barker (1976) listed six cues that individuals generally use in detecting the contamination of air quality. These include poor visibility, dust accumulation, odour nuisance, discolouration of building as also material damage, eye irritation and respiratory suffocation.

Instead of simultaneously measuring the physical indoor (home) and outdoor concentrations of pollutants, subjective judgments were taken as the prime data in the present study. Each respondent rated the indoor air quality of his/her residence in terms of (a) freshness of air inside the house, (b) difficulty in breathing inside the house and (c) presence of smoke, soot and dust particles inside the house. Based on their ratings, an IAQI has been developed.

The level of indoor air quality in Calcutta proper has been studied here in relation to possible emissions from kerosene stoves, coal ovens, electric heaters and gas ovens, as reported by male and female respondents. We specifically attempt to answer some questions as to how the perception of the indoor air quality is associated with the type of oven and fuels mainly used for cooking purposes. Is it true that use of kerosene heater or coal oven can so contaminate the indoor air quality that it could be detected and reflected in the

respondent's assessment of the freshness of air inside the house? How do the residents of Calcutta proper who use gas stove, coal ovens or kerosene stove for cooking purposes generally rate the indoor quality of air ? Is there any association between types of fuels used for cooking and indoor air quality ? Do the empirical data indicate that those using coal oven or kerosene stove tend to perceive the air quality inside the house to be more stuffy than those using gas stove ? If so, what are the socieconomic correlates of coal consumption. Similarly, we can question whether the level of perceived indoor air pollution is any way associated with the perceived magnitude of cigarette smoking inside the house. If these are associated, then what is the relationship between (a) indoor air quality and (b) reported amount of cigarette smoking inside the house, on the one hand, and (c) number of sick persons in the household and (d) number of family members suffering from asthma, on the other hand ? In an attempt to answer each of the above questions, we present in this paper the results of an intensive analysis of the data collected from 1,724 residents of Calcutta proper who were personally interviewed for their opinions, perceptions and attitudes connected with outdoor and indoor pollution.

MATERIAL AND METHOD

The sampling plan, the main contents of the interview schedule which was employed in the study and the data base are all described in a previous publication (Mukherjee, 1993). The survey was conducted in 56 localities within the jurisdiction of the Calcutta Municipal Corporation (CMC) which were selected in the first stage by simple random sampling without replacement (SRSWOR) from a total of 5,787 NSS blocks of Calcutta proper. From each of the selected 56 blocks (listed in Table 2), a preassigned percentages of male and female adults (18 yrs and above) were selected in the second stage from each stratum by SRSWOR procedure after the adult population of Calcutta proper was stratified into (a) illiterate, (b) literate and (c) educated groups. The stratification was based on door-to-door house listing. The details of the sampling procedure are discussed in a previous publication (Mukherjee, 1993). Completed and coded questionnaires properly scrutinized were available from a total of 1,724 adult respondents, 719 females and 1,005 males. These were processed by a main-frame computer and subjected to different types of statistical analysis, both univariate and multivariate.

For assessing the sample respondent's perception of indoor air quality, the following three questions were asked to all respondents in the following sequence:

1. What is the extent to which you find it easy to breathe freely while at home ?
2. How frequently do you find smoke, dust particles or soot inside your house?
3. How do you feel about the freshness of air inside your house?

The above-mentioned three questions pertain specifically to the following three aspects of indoor air quality: (a) breathing discomfort, (b) dirt accumulation and (c) stuffiness and staleness. Answers to the first and last questions could be coded in terms of three graded response categories. Residents not finding any trouble in breathing or always finding the air to be fresh inside the house, were given a score of one each for these answers. Similarly, those who said that they felt frequently troubled while breathing at home in response to the first question, were given a score of three. In the same way, those who answered that they found the air to be always stale and stuffy in response to the third question were given a score of 3. For this question, a score of 2 was given to answers indicating some stuffiness. Similarly, a score of 2 was assigned for responses indicating some trouble in breathing with reference to the first question.

In the case of the second question, those who never found any dust particles, smoke or

soot inside their house were given a score of one. Those who always found any of these dirts were given a score of four only. The indoor air quality index, hereafter referred to as, IAQI, is the unweighted sum total of scores received on the afore-said three questions. The theoretically possible range of this index is therefore 10-3 = 7. A score, say as high as 7 or above is indicative of bad quality of indoor air quality whereas a score as low as 4 or 3 reflects tolerably good indoor air quality.

For obtaining some idea as to how the indoor air pollution is contributed by cigarette smoking, the following question was asked to each sampled resident:

"How many cigarettes do you/your spouse and other members of your household generally consume on the average per day inside your house ? The exact number of cigarettes so consumed was recorded for a parametric anaysis.

In addition to these questions, an inventory was taken of the type of ovens generally used in the sampled resident's house and the fuel mainly used there for cooking purposes. Questions were also asked as to the number of sick persons and number of family members who were suffering from asthma.

RESULTS

Analysis of the data obtained from a total of 1,724 residents of proper Calcutta revealed that although about 40 per cent of them reported that they had no trouble in breathing freely inside their house, a large percentage complained about occasional troubles. About 11 per cent reported that they frequently experienced trouble to breathe freely while at home. About 62% of the residents complained about the frequent presence of dust particles/soot/smoke inside their rooms. Nearly 64% of the residents felt that the quality of air inside their houses was sometimes quite stale and stuffy. About 9% of the sampled residents complained that their rooms were always stuffy because of indoor air pollution.

Stratum-wise Differences in the IAQ Components

Table 1 shows the stratum-wise percentage of households where the sample respondents complained about the cleanliness, stuffiness and troublesome nature of indoor air quality in their respective houses. These three aspects of indoor air quality are moderately correlated with each other, the average inter-correlation being 0.52. It is seen from table 1 that respondents from educated stratum in general made less complaints about all the afore-said three aspects of indoor air quality than illiterate and just literate respondents. This is so because in the case of households of the former stratum, gas oven is generally used whereas in the case of the latter, either coal, wood and/or kerosene are the main fuels used for domestic cooking. For example, coal is consumed only in 32.27%

Table 1: Percentage of households complaining about breathing trouble due to bad indoor air quality, percentage always finding smoke/soot inside and percentage reporting stuffiness/staleness inside: By Stratum

Component of indoor air quality	*Stratum name and sample size*						
	Illiterate Male (N=144)	*Illiterate Female (N=169)*	*Literate Male (N=97)*	*Literate Female (N=87)*	*Educated Male (N=764)*	*Educated Female (N=463)*	*Total Sample (N=1724)*
Percentage frequently troubled	22.92	21.30	11.34	12.64	8.54	8.42	11.40
Percentage always finding soot/dust	14.58	37.87	17.53	28.74	16.49	30.24	22.80
Percentage sometimes finding stuffiness	65.97	65.68	68.04	48.28	72.12	49.68	63.70
Mean indoor Quality Index (IAQI)	6.76	6.94	6.60	6.19	6.22	6.12	6.33
S.D. of IAQI	1.56	1.52	1.54	1.73	1.41	1.58	1.53

Table 2a: Percentage of different types of inconvenience (as reflected in the answers to three questions on indoor air quality): As experienced by four types of oven-users

Types of oven used[1]	*Frequently troubled*	*Always finding soot/dust*	*Sometimes stale/stuffy*
	(N=197)	*(N=393)*	*(N=1098)*
Coal oven	78.17	78.37	72.77
Kerosene stove	65.48	73.03	77.32
Electric heater	2.03	2.54	2.64
Gas oven	12.18	22.39	20.67

1. The categories of different types of ovens used are not mutually exclusive, *i.e.*, there are many households using both coal oven as well as kerosene stove. For this reason, the percentage shown in any column do not add up to 100 but much more than that. The sample sizes shown in the parantheses are the number of residents experiencing a particulatr type of inconvenience, as expressed in their responses to three questions on indoor air quality.

Table 2b: Percentage of responses to three questions on indoor air quality indicating unsatisfactory state of affair as expressed by households using different types of fuels[1] for domestic cooking

Types of fuel mainly used for cooking	*Answers to three independent question on air quality*		
	Frequently troubled	*Always soot/dust*	*Not fresh*
	(N=197)	*(N=393)*	*(N=1296)*
Coal	47.72	32.57	48.57
Wood, garbage	3.05	1.27	2.47
Briquette	15.74	9.41	13.77
Kerosene oil	20.30	34.35	15.60
Electric	0.50	0.00	0.16
Natural gas	10.15	20.61	17.60
Not applicable	2.54	1.78	1.83

1. Mutually exclusive categories of fuel types such that each column total should show 100 per cent of the sample households.

of the households in the educated stratum whereas the corresponding percentage is 46.00% in the households belonging to people of illiterate and just literate strata.

Experience of Indoor Air Quality as a Function of Fuels/Ovens Used

Results reported in table 2a clearly show that the greatest percentage of inconvenience is reported by those respondents who use coal oven and/or kerosene stove in their houses. About 80% of the coal oven users reported their inconvenience by the impure nature of indoor air quality. About the same percentage complained about the presence of dust particles/soot/smokes inside their house. In the case of users of mainly kerosene stoves, nearly the same percentage complained about the staleness or stuffiness in the rooms. In contrast to these groups, the users of electric heaters are almost trouble-free so far as indoor air quality is concerned. Only about one-fifth of the households using gas ovens are found to make some complaints about the staleness/stuffiness of the indoor air.

More or less the same conclusion is reached from the results reported in table 2b. It is seen that among those 197 respondents who complained of frequent troubles in breathing while at home (because of impure indoor air quality), the highest percentage (about 48%) are mainly using coal as the domestic fuel. Only 20.30% are reported to be using kerosene oil for cooking purposes. Similarly, among the 1,256 respondents who complained that the indoor air was *not* fresh, about 48.6% of them were using coal. As fuels for domestic cooking, only 17.6% and 15.6% were users of liquid gas and kerosene oil, respectively. Thus, consumption of coal for cooking purposes is found to be the most important contributor in polluting the indoor air quality in respect of its freshness, cleanliness and stuffiness.

The results of separate analysis of variance (ANOVA) reported in table 3 shows along with the results of table 4 that in terms of all the afore-said aspects of indoor air quality, there is a statistically significant ($p < 001$) difference between those using coal ovens and those using gas stoves. A multivariate analysis of variance (MANOVA) using all the three

Table 3: Results of Separate Univariate Analysis of Variance (ANOVA) one each of the three separate aspects of indoor air quality for testing the mean difference between households classified by types of oven mainly used for domestic cooking

Aspects of indoor air quality	*Sum of squares*[1]		*Mean sum of squares*		*Main ANOVA result*	
	Between	*Within*	*Between*	*Within*	*F statistic*	*Probability*
Freshness	18.833	551.425	6.278	0.321	19.580	0.000
Stuffiness	20.390	728.598	6.797	0.424	16.045	0.000
Soot/Smoke/Dust	15.378	1211.181	5.126	0.704	7.279	0.000
Indoor Air Quality Index	143.928	3862.935	47.976	2.246	21.362	0.000

1. The degrees of freedom associated with between S.S. and within S.S. are 3 and 1720, respectively. The groups compared here are (1) Coal oven users, (2) Users of kerosene stoves, (3) Electric heater users and (4) Gas oven users.

variables jointly also revealed a significant over-all difference between groups classified on the basis of ovens used frequently for cooking. The multivariate F statistic corresponding to Hotelling's trace criterion of 0.0488 turned out to be 9.309 which for 9 and 5150 degrees of freedom (df.) is statistically significant beyond the .001 level.

Indoor Air Quality Index

The sample respondents' scores on all the three aspects of air quality were combined in view of their positive intercorrelations by just summing them. The average intercorrelations being 0.52, as stated already, the standardized item reliability of the IAQI turned out to be 0.7647 which as measure of Cronbach internal consistency reliability is satisfactorily high.

The afore-said unweighted IAQI also showed, as expected, a significant overall group difference. Respondents using mainly coal ovens were found in general to score higher on this index than respondents using gas or electric heaters. For example, as many as 526 out of 1,062 coal users scored 7 or above on IAQI while among the gas users, only 116 out of 383 scored such high IAQI. Since a high score on IAQI is indicative of bad indoor air quality, the results suggest that coal oven users generally experience more inconvenience with respect to their indoor air quality than users of gas ovens.

The results of ANOVA of the index are displayed in the last row of table 3. The results together with those shown in the bottom panel of table 4 clearly indicate that as compared to the households mainly depending on gas stoves, the households mainly using coal ovens and kerosene oil have, in general, significantly more unsatisfactory IAQI. The gas users as a group received the lowest mean score on this index while the coal oven users were found to have the highest mean indicating that the latter group expressed more inconvenience with the indoor air quality than the former group. These groups differ substantially because the 95% confidence interval (CI) of the means for the two groups do not show any overlap, as can be seen from table 4. However, the difference between the coal oven users and kerosene stove users does not appear to be statistically significant even at the 0.05 level. The descriptive statistics for the groups classified in terms of the main types of cooking ovens are shown in table 4 and they amply indicate that all the distributional assumptions for running an ANOVA and other parametric analyses connected with IAQI are fully satisfied. The results displayed in tables 3 and 4 also indicate that consumptions of coal and kerosene for cooking purposes appear to be the most important contributors polluting

Table 4: Cumulative percentage distribution and descriptive statistics of indoor air quality index derived for 1724 respondents of households classified by types of fuels mainly used for cooking purpose

Value of Indoor Air Quality Index	*Electric*	*Gas*	*Coal*	*Kerosene*	*Total*
	(N=37)	*(N=383)*	*(N=1062)*	*(N=242)*	*(N=1724)*
3	5.4	7.0	2.4	2.1	2.4
4	10.8	20.4	8.8	6.5	11.1
5	29.7	42.3	22.8	23.1	27.3
6	64.9	69.7	50.5	57.0	56.0
7	78.4	85.6	78.2	82.2	80.4
8	94.6	96.3	90.6	93.8	92.4
9	97.3	98.4	95.6	97.1	96.5
10	100.0	100.0	100.0	100.0	100.0
Mean	6.189	5.802	6.513	6.380	6.330
S.D.	1.543	1.543	1.509	1.398	1.525
95% CI	6.04-6.35	5.65-5.96	6.42-6.60	6.21-6.55	6.26- 6.40

the indoor air quality. Thus, coal ovens and kerosene heaters can contaminate indoor air so badly that it is reflected in the respondents' subjective assessment of the air quality.

The afore-said conclusion is further supported by the results reported in terms of the pie charts of figure 1. Based on the IAQI (unweighted sum of scores or ratings obtained on three aspects of indoor air quality as discussed above), the sample respondents were classified into two groups. Those 44 per cent of the respondents whose ratings were 7 or above on the IAQI were grouped as bad while those scoring 6 or less were classed as tolerable group. The pie chart on the right hand side represents the tolerable group while the one at the left hand side stands for the respondents whose IAQI was found to be 7 or above (bad group).

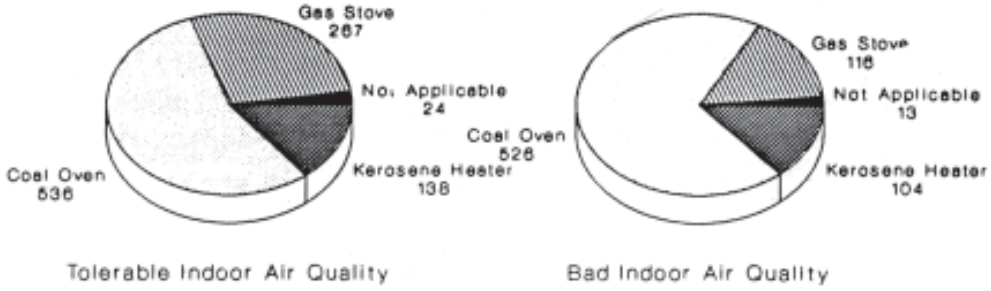

Fig. 1. Pie diagrammes showing fuels mainly used by households having bad and tolerable Indoor Air Quality

Table 5: Frequency of households with Indoor Air Quality Index above and below the cut-off point of IAQI: By types of locality

Group above or below Cut-off IAQ Index	*Frequency of households in different types of localities*					*Total frequency of households*
	Residential	*Commercial*	*Industrial*	*Mixed*	*Slum*	
Below 6.1	575	25	65	216	84	945
Above 6.1	315	20	73	198	153	759
Column Total	890	45	138	414	237	1724

The chi-square test of homogeneity of the two distributions below and above the cut-off point of 6.10 yielded a chi-square value of 74.29 which for 4 d.f. is statistically significant at the .0001 level.
The Mantel test of trend also showed a chi-square value of 64.62 which for 1 d.f. is significant at the .001 level.

It is seen that the proportion of coal oven consumers in the two groups differ substantially, the percentage being much higher (69.30%) in the bad group than in the tolerable group (55.54%).

Some Correlates of IAQI

The IAQI was found to show statistically an overall stratum difference (F = 11.09 which for 5 and 1718 df. is significant beyond the .001 level). In general, both educated male and female respondents as well as just literate male respondents reported significantly better indoor air quality at their houses than illiterate respondents. The indoor air quality showed statistically significant relationship with respondent's education, occupation, family expenditure and gender. Since households which are economically well-off generally use gas ovens and those which are relatively not so well-off use coal ovens, woods and kerosene for cooking purposes, significant correlations are found between various indicators of economic status such as assets, family expenditure, average monthly electric bill, number of rooms, and condition of the respondent's house, on the one hand, and indoor air quality on the other. However, occupational status did not show any significant relationship with indoor air quality. The results are more or less the same for both males and females.

Indoor air quality was found to be quite bad in the slum areas in general than in other areas of Calcutta proper as can be seen from table 5. Among the 237 respondents respondents residing in slum areas, about 65 per cent of them were found to have unsatisfactory IAQI (7 or above). The corresponding figure in the residential areas is about 35 per cent. In the non-slum areas, a score of 7 or above in the IAQI was found in the case of exactly 606 residents out of 1,487 resident (40.75%). Thus, there is a significant association between type of locality and indoor air quality (χ^2 = 74.29 which for 4 df. is significant beyond the 0.001 level). In terms of the mean level of IAQI also, the slum areas scored 7.063 with a 95% confidence interval (CI) ranging from 6.865 to 7.261. In the case of non-slum areas (N = 1,487), the mean was found to be 6.213 with a CI ranging from 6.137 to 6..288. The difference between the two groups of residential areas with respect to the mean level of IAQI is statistically significant at the .001 level (t = 8.126).

Some localities of Calcutta proper were found to have significantly higher indoor quality index than others. A good deal of variation was observed in this respect from one locality to another. Of all localities, residents of Tarpanghat Road in South-east Behala and Jhil Basti of Dhakuria were found in general to complain more often about the unhealthy state of indoor air quality in their houses. In these two localities, the mean IAQI turned out to be 8.67 and 8.20, respectively (out of the

maximum possible score of 10). The mean index ranged from 7.00 to 7.38 for households located at Muktaram Babu St. in North Calcutta, Tiljala Masjid Bari Road, Vanga Mahalla, Sahitya Parishad Basti area, and Rambagan slum area. In contrast, the mean IAQI for Jadu Colony, a posh locality in Behala, was found to be 4.18 only. The results indicate that localities inhabitated by high middle class families in general were found to have a fairly good air quality inside their houses. Instead of using coal ovens, most of these families in such localities almost invariably use gas stoves for cooking purposes. As against this, respondents living generally in slum areas and/or localities dominated by poor section of the society were found to complain about all the three aspects of indoor air quality. As stated already, coal and kerosene oil are found to be main fuels for them for domestic cooking.

Some Correlates of Coal Consumption

A significant point biserial correlation of 0.1526 was found between coal consumption and IAQI. When households mainly using coal as the fuel were scored as 1 and those not using it were scored as zero, the product-moment correlation with number of family assets (r=-0.3939), condition of the respondent's house (r=-0.3001), his level of education (r=-0.2989), number of rooms (r= -0.2349), family expenditure per month (-0.1230) and average monthly electric bill (r=-0.2632). The findings are comparable for males and females. Thus, the percentage of houses using mainly coal oven for domestic cooking is substanitially higher for those houses which are economically not so well off than those owned by families with high socio-economic status.

Coal ovens were reported to be used by about 61.6 per cent of the sampled households in Calcutta proper. About 68 per cent of the respondents from illiterate stratum stated during the interview that coal oven was still then being used for cooking purposes in their residence. In the case of literate and educated strata, the corresponding figures were 56.52% and 53.79% respectively. Interestingly, more males (61.39%), reported about the use of coal oven than females (51.32%). Other gender differences in the area of perceived air quality will be reported in a subsequent paper.

When the sample respondents were asked as to whether they were willing to switch over to briquette burning from coal, if cost and supply were not factors, about 23.5% expressed their willingness for such a change. More than one-third of the respondents, however, expressed their inability. About the same percentage reported that they had just switched over to briquette burning from coal. A similar question was asked regarding the possibility of switching over to gas oven from coal oven. About 48% of the total respondents expressed their inability in this regard, their main reason being fear of accident (15.5%) and lack of space (15.7%).

From the results of the present survey, it is found that not many residents of Calcutta proper are in favour of banning coal burning. Although 73.5% of the sample respondents agreed with the statement that "coal burning makes it difficult for people with respiratory problems", only about 37 per cent of them endorsed the attitude statement that "coal burning for domestic purposes within Calcutta city must be stopped by legal measures". Interestingly, those who more often endorsed the latter statement also reported more often the presence of at least one elderly asthma patient in the household (r=0.06, prob.=0.01). Despite these findings, about 46.1% of the respondents agreed with the statement that "coal burning for cooking should be allowed because the amount of air pollution it causes is small as compared to other sources such as lorries, trucks and buses". About 34 per cent of the respondents could neither agree nor disagree

with the above statement. They were just undecided.

Indoor Tobacco Smoking and Its Correlates

Although indoor cigarette smoking has been found in previous studies to be an important polluter of air inside the house, the present study failed to find any conclusive evidence of it. As can be seen from table 6, the number of cigarettes reportedly consumed on the average per day has little relationship with any of the three aspects of indoor air quality which were examined in this study. It is true that good ventilation might be reducing exposure to environmental cigarette smoke to many of our respondents but it generally does not totally eliminate it. Because smoking produces large amounts of pollutants, natural or mechanical ventilation procedures do not necessarily remove them from the air inside the rooms as quickly as they build up. Yet, the data of the present study indicate that the smoke around the rooms resulting from indoor cigarette smoking may be disappearing without causing much inconvenience to the respondents and hence, they did not complain of any indoor pollution resulting from cigarette smoking inside the house.

Table 6: Product moment correlation between different aspects of indoor air pollution and total number of indoor cigarette smoking (N = 1, 724)

	Correlation between			
	Freshness	*Stuffiness*	*Soot/ Smoke*	*IAQI*
No. of cigrette smoking per day	-.03	.04	.04	.05

Interestingly, indoor cigarette smoking showed a positive relationship with economic status only in the case of male respondents, the higher the economic status, the more the number of cigarettes smoked indoor. This relationship is totally absent in the case of females.

The results of the present survey showed no association between number of cigarettes reported to be consumed indoor and number of persons reported to be sick due to air pollution as well as number of asthma patients in the household. The results are more or less the same for both genders.

Indoor Air Quality and Health Problems

Since perceived indoor air quality is believed to be not so satisfactory in the slum areas in comparison to residential areas, as has actually been found in the present study, it was expected that there would be higher incidence of health problems in the former areas as compared to the latter. IAQI in the present study showed a statistically significant correlation of 0.06 with total number of asthma patients in the household. Although the obtained correlation based on N=1724 is significant at the 0.01 level, still it is very low. Similarly, the type of locality (slum=1, non-slum=0) showed quite a low biserial correlation of -0.057 with number of elderly asthma patients.

The average number of sick persons in the slum households was found to be 0.10 as compared to 0.11 in the non-slum areas, the difference being statistically not significant even at the 0.10 level. A similar result was obtained with respect to the total number of asthma patients in the household. Thus, the expectation that there would be more number of sick persons and/or more number of asthma patients per household in the case of slum areas as compared to non-slum areas is not supported by the findings of the present survey.

Equally interesting was the result concerning the lack of relationship between indoor air quality and health variables. No significant association emerged when the number of sick persons in the household were cross- tabulated against IAQI. In no case, the product-moment

correlation between these two variables turned out to be significantly different from a zero correlation.

No gender difference was found with respect to the correlations between IAQI and number of sick persons in the household. An exactly similar finding emerged with respect to the correlation between number of asthma patients and IAQI. All the obtained correlations were found to be statistically no way different from a zero correlation.

However, the results indicated that most of the people complaining respiratory troubles due to air pollution generally live in houses where there is always some trace of soot due to bad indoor air. Similarly, out of the 179 residents who reported the presence of one or more asthma patients in the household, about 68% frequently found smoke, dust particles or soot inside their house. The data also revealed a strong association ($\chi^2 = 15.05$ with 2 d.f., prob. =.00054) between the number of asthma patients in the household and degree of trouble experienced by residents due to bad indoor air. Among the 71 households where at least one elderly asthma patients resided, 58 (about 81%) of them complained of unclean and troublesome indoor air quality. Similarly, out of 104 sample households complaining some kind of respiratory troubles among the household members due to air pollution, 79 households (about 76%) reported that the air inside their house was frequently stale and stuffy. Among the 219 sample residents who reported that either they or their family members were actually affected by air pollution, a total of 151 (about 69%) of them admitted that they experienced at least some occasional troubles in breathing while at home due to indoor air pollution. The product-moment correlation between number of elderly asthma patients and experience of trouble in breathing inside the room was found to be 0.0823 which although low is statistically significant at the .01 level. Those using coal ovens reported on the average 0.048 elderly asthma patients in the household while those not using it reported on the average only 0.025 elderly asthma patients, the mean difference being statistically significant at the .05 level (t=2.146 which for 1722 d.f. is significant at the .032 level). A similar result was found with respect to number of sick persons in the household.

DISCUSSION

The present investigation based on a sample survey of Calcutta residents shows clearly a strong association between indoor air quality and the type of fuels/ovens mainly used in the kitchen. Households mainly using coal ovens and/or kerosene stoves were reported to be experiencing in greater percentages the inconvenience caused by smoky rooms than households using gas or electric stoves for cooking purposes.

Indoor air quality was also found in the present study to vary from one type of residential area to another. As expected, it was reported to be quite bad in slum areas than in residential areas. Respondents belonging to some localities were found to have reported significantly higher indoor air quality index than other suggesting that they experienced in greater proportion the stuffiness of indoor air, uneasiness in breathing and dirts as also soots inside the rooms. Of all the 56 localities which were surveyed, residents of Tarpanghat in Southeast Behala and Jhil Basti of Dhakuria in the southern part of proper Calcutta were found in general to complain more often about the inconvenience caused by indoor air pollution. In contrast, residents of Jadu Colony expressed in greater proportion their satisfaction about the freshness of air, both inside and outside the house. In general, residents living in localities where the majority hailed from well-to-do families, reported more often about a trouble-free indoor air. Instead of using coal ovens, most of these families were using gas ovens rather than coal ovens. Residents living in

slums or in some localities where the majority of them were from low socio-economic class, tend to report in greater proportion of the unhealthy state of indoor air quality. In most cases, they were found to be using coal oven, wood, dry garbage and/or kerosene stoves for domestic cooking. For this reason, residents of slum areas tend to complain about stuffiness of the indoor air, frequent troubles in breathing, and accumulation of dust, soot and other particles inside their rooms.

A substantially high percentage (61.6%) of Calcutta residents were found to be still using coal as a domestic fuel. Despite the availability of liquid gas cylinders, even 53.8% of the residents belonging to the educated stratum were using coal for cooking purpose. Unless the price of cooking coal is not excessively increased, Calcutta residents, particularly those living in slum areas will continue to use coal ovens. Because of easy availability and fuel energy efficiency factor, coal is still being used as a domestic fuel and people have not internalized the norm of not using coal. The survey findings indicate that this is true even though about 74% of them are found to be aware of the fact that smoke from coal burning can be dangerous for asthma patients. Very few households, especially in slum areas can afford a smokeless or ventilated *'chullah'* or gas. For this reason, there is a need for ventilation improvement especially in homes located in the densely populated areas of Calcutta.

When we consider factors affecting ventilation such as the area of opening, permeability of walls and roof, the wind velocity and the direction of the wind etc., we can still imagine the condition of smoky kitchens in the poorly built houses of residents who are economically not so well-off. Despite this possible hazardous condition of the kitchen, there is no significant difference in terms of the average number of sick persons or asthma patients in slum areas where the mean level of indoor air quality is relatively worse as compared to the non-slum areas. Notwithstanding this fact, the lack of any relationship between IAQI and health problems suggests that the coal oven is frequently used outside the residential place especially before it is ready for cooking. This is supported by the survey findings that about 50 per cent of the residents in slum areas lit the movabe coal-oven in the open space. Only about 16% are complelled to use it inside the kitchen. Therefore, one can not expect much problem of a continued exposure to indoor air pollution in the case of slum dwellers. For possibly this reason, no evidence was found concerning a significant relationship between number of persons sick in the family (or number of asthma patients) and the indoor air quality, as expected.

However, if domestic coal consumption is going to continue in Calcutta proper, then some effort should be made to sensitize the residents with the need for improving ventilation condition in the kitchen (Ahuja, 1985, p.19). They should also be sensitized with the possible hazards of coal burning and use of kerosene stoves. Although a little more than one-third of the residents reported that they had just switched over from coal to briquette burning, a more or less same percentage expressed their inability for such a change over. Through mass media and tactful intervention of local youth clubs, these groups of residents should be pursuaded to switch over to briquette burning for domestic cooking. Since about 23 per cent of the sampled Calcutta residents were always finding soot, dust particles and smoke inside their houses, these facts should be brought to their attention in order to impress upon them the personal cost of air pollution in Calcutta proper. Similarly, those complaining about breathing difficulties due to bad indoor air quality must be made aware of their personal health problems arising from pollution. Television programmes can neatly document these facts and thereby the effects of both indoor and outdoor air pollution could be demonstrated to the masses to arouse on their part sufficient degree of concern (Mukherjee, 1993).

The data of the present study indicated almost a total lack of relationship between the index of indoor air quality and the total number of cigarettes reported to be consumed in the house. No evidence was also found for the support of the frequently stated hypothesis of an association between health status of family members on the one hand and the quality of indoor air, on the other, especially when it is polluted by smoky ovens and cigarette smoking inside the room. However the data indicated a strong association between number of elderly asthma patients in the household and degree of trouble experienced by the resident due to bad indoor air. It appears that in many cases, the smoke around the kitchen and other rooms caused by indoor smoking does not remain there for long even though the houses in most localities in Calcutta proper are not so well ventilated, especially if they are located in the ground floor of houses in the densely populated areas. In any case, the finding suggests that indoor cigarette smoking may not be preceived as a cause of indoor air pollution. But smokes coming from coal ovens or kerosene stoves are certainly found to be important source of indoor air pollution. These are also perceived to be unhealthy by residents in whose house there is at least one asthma patient.

The perceived magnitude of indoor smoking was found to be no way related to health problems, especially among young adults. Although no single compound is responsible for the sensory effects of indoor air, the effects being the result of complex interactions between compounds and host related factor (Berglund et al., 1984), some studies have shown a clear association between reported number of medical symptoms and bad air quality indoors. In the present study, it was therefore, expected that residents experiencing bad indoor air quality will not only complain about the immediate health effects of indoor air pollution such as eye, nose and throat irritations, headaches but also some symptoms and diseases which are believed to be the resultant of a long series of repeated exposures to bad indoor air pollution, such as asthma, emphysema, heart disease and even cancer. Epidemiological studies suggest a relationship between air pollution, both indoor and outdoor, and the incidence of human lung cancer, as already pointed out in the introductory section. Thus, although household smoking has been found to be a substantial contributor to RSP exposure which is hazardous for health, no such association could be clearly established on the basis of the results of the present survey. It appears that the data on health problems collected in this survey are not extensive enough to reflect the sickness status of individual members of the household. More information is required in order to identify different kinds of health problems which might arise out of indoor air pollution. As such, the relationship between indoor air quality and indoor smoking on the one hand and health problems of family members, on the other hand, could not be clearly established. This is one distinct research area which future studies in indoor air pollution should deal with.

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