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A comparative study on exposure to indoor air pollution among the urban, sub-urban and rural populations of Jalgaon district

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ABSTRACT

In developing countries the majority of people rely on solid biomass for cooking and heating which results in poor indoor air quality. This study investigated the indoor air quality of rural, sub-urban and urban houses in Jalgaon District of Maharashtra state. The study was undertaken to estimate the indoor dust concentrations and their effects on the rural, sub-urban, and urban public. The study shows considerable high concentration of particulate matter particularly in the kitchen using biomass as fuel in the rural areas as compared to urban areas. As a part of study 600 houses were surveyed for indoor air quality from rural, sub-urban, and urban areas. The health assessment (n=600) of exposed population was done by conducting the pulmonary function test with these areas. The women are exposed to the indoor house environment for a longer period and are most vulnerable to the indoor biomass smoke. The male are less exposed to indoor environment as compared to the female. Significant declines in forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), Forced Expiratory Flow 25-75 (FEF25-75) and peak expiratory flow rate (PEFR) was observed in the rural public as compared to sub-urban and urban. The study confirmed the reduction in lung efficiency in female as compared to male. Ventilatory impairment shows that most of the subjects come under the category of moderate and severely affected. The symptoms of respiratory diseases like frequent coughing, irritation in respiratory tract, and shortness in breath were observed in the exposed population.

KEYWORDS

Dust exposure;
FVC;
FEV_1;
PEFR;
FEF25-75.

INTRODUCTION

Indoor Air pollution has been identified as a potentially serious environmental public health problem in India. According to the 1991 Indian National census, in rural India nearly 72% of households rely on wood and crop residues while about 20% on kerosene and dung as their primary fuel. Particles generated from burning of the biomass fuel are capable of reaching the human lungs during respiration process and may cause respiratory problems. Particulate matter less than 10 micron (PM_{10}) has direct relations to the human health. Studies have indicated that the exposure to smoke form indoor air pollution can cause chronic obstructive pulmonary disease, asthma and bronchitis, lung cancer, and tuberculosis[9,10].

In poor communities, the continuous use of the biofuel combustion results in deteriorating housing conditions. In the rural areas, women spend around 90% of their times at indoors. They were exposed to the elevated levels of indoor air pollutants. According to World Health Organization (WHO) estimates human exposure to indoor pollutants is 1000 times greater than the same release at outdoor environment. A large variation of particulate matter has been recorded in kitchen environment due to the variety of biomass fuel used during cooking[5,10,15].

Estimates proved that 28% deaths occur due to indoor air pollution in India related to the use of biomass fuels[4,5]. The use of fuel is determined by the economic status of the population. Padmavati et al.[4,5,13] reported that chronic obstructive pulmonary disease (COPD) occurs 10 to 15 years earlier in women exposed to indoor air pollutants. This shows higher prevalence of COPD in women due to exposure to domestic air pollution as a result of solid biomass fuel burning. The studies with case-control designs reported the association between exposure to biomass smoke and chronic bronchitis or COPD.

The most commonly reported health effect of indoor air pollutants are increase in the incidences of respiratory morbidities viz. respiratory illnesses, cancer, tuberculosis, perinatal outcomes including low birth weight & eye disease[6,10]. Large number of studies in developing countries has reported the association between exposure to indoor air pollution and acute lower respiratory infections[2,14]. The women cooks are exposed to far higher concentrations than other household members and adult men experience the least exposure in rural houses of southern India[4,5]. The multiple house variables such as the type of fuel, stove fuel, kitchen type, kitchen ventilation, roof material, and wall material plays vital role on actual exposures of household to indoor air pollutants. Kitchen configuration is an important determinant of pollutant concentrations in solid-fuel user but not in gas-using houses[5,10,15]. Tata Energy Research Institute (TERI) configured such few variables of house as per the utility of fuel[8].

In the present study author aims to monitor indoor air environment and its effects on the urban, sub-urban, and rural households in Jalgaon district. Temperature, humidity and dust concentration was monitored for the urban, sub-urban and rural houses. The spirometry includes the lung functions such as forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), peak expiratory forced volume (PEFR) and Forced Expiratory Flow 25-75% (FEF25-75). The questionnaire was used to determine the respiratory symptoms in the urban, sub-urban and rural households in Jalgaon district.

MATERIAL AND METHODS

Study area

Jalgaon district is located on the northwest region of the state of Maharashtra and lies between 20° and 21° north latitude and 74°55′ and 76°28′east longitude. The Jalgaon district is of 11,765sq.km and over 40 lacks of population. As per the census of 2001 the district has 28lakh rural populations. This includes 40% below poverty line population of the district.

Study population

The campaign was conducted by the authors in the rural areas to create awareness about indoor air pollution and its health effects on human being. The study subjects comprised 100 males and 100 females of rural, sub-urban, and urban areas. The data on demographic characteristics of the subject was collected during the questionnaire survey. These include age, gender, weight and height. It was confirmed that none of the subjects had respiratory tract symptoms such as cold or cough during Spiro metric testing.

Houses characteristics survey

The data on characteristics of houses in the study area was generated by actual survey during sampling. All the variables are given in the percentage. The kitchen patterns used are without partition, with partition, outdoor kitchen and separate kitchen. Kitchen ventilation was assessed qualitatively by the variables poor, moderate, and good. Stove types were divided into traditional three stone stoves, chulla with mud & ridges, LPG gas, and kerosene stove. Then the types of fuel used were wood, agro waste (grass, leaves, trash, and crop waste), LPG gas, kerosene, and dung. Variables used for roof and wall material was earthen, wood, metal sheet, and cement concrete.

Indoor environment

Indoor micro-environmental parameter like temperature and humidity was monitored. Individual dust exposure of the households was measured by using the handy dust exposure sampler (AS-2, Technovation Analytical Instruments Pvt. Ltd., India) for 8 hours. Households were required to wear a personal monitor designed to collect particulate present in the air close to the subjects breathing zones.

Respiratory status

Forced vital capacity (FVC) is the maximal amount of air that can exhale following maximal inspiratory effort (Normal: Male 4.8L, Female 3.1L). Forced expiratory volume (FEV_1) is the volume of air exhales in one second during a forced vital capacity effort; peak expiratory flow rate (PEFR) is the maximum amount of air exhaled with forced effort during the FVC, and FEF 25-75% (FEF 25-75) is the average flow during 25-75 percent of forced vital capacity. FEF25-75 is the sensitive index of large airway obstruction present in most clinical conditions such as asthma and COPD. Before spirometry test of the household's age, height, weight and gender were fed in to the spirometer. Spirometer gives two values viz. predicted and actual. The predicted values are based on the age, height, weight and gender of the subject, while the actual values are based on the maximal exhalation followed by maximal inspiration. The pulmonary function test was conducted by sitting the subject comfortably in a chair. Regular sterilization of mouthpieces was done before the use. The subjects were asked to maximum exhalation followed by maximum inspiration. Three such tests were performed and subjects were asked to improve the performance. Best of three performances of FVC, FEV_1 and PEFR were taken into the consideration.

The equations for prediction were as follows -

FVC (L)=0.050H-0.014A-4.49

FEV_1 (L)=0.040H-0.021A-3.13

PEFR (L /Sec) =0.071H-0.035A-1.82

Where, H is height in cm and A is age in years.

FVC : Forced Vital Capacity- is the maximum amount of air that can be exhaled following a maximal inspiratory effort.

FEV_1 : Forced Expiratory Volume in one second- is the volume of air exhaled in one second during a forced vital capacity effort.

PEFR : Peak Expiratory Flow Rate- it is the maximum amount of air exhaled with forced effort during the FVC.

FEF 25-75 : Forced Expiratory Flow 25-75 % is the average expired flow over the middle half of the FVC.

The results of spirometry were assessed according to the criteria given in the manual of the Medspiror.

Health survey

There is an increasing interest in measurements of perceived health status in clinical settings as well as health survey. Self-reported survey among the subjects is most frequently assessed health perceptions in epidemiological research. The questions were adopted from the Respirator Medical Evaluation Questionnaire (OSHA, 1998) for collection of the data. The data was then processed for no difficulty in respiration and difficulty in respiration. The difficulty in respiration was assessed by the variables viz. pain in chest, frequent coughing, and irritation in throat. The definition used is chronic cough: cough production for at least 3 months a year for not less than 2 successive years[16].

Statistical analysis

The data was processed for mean and standard deviation of demographic characteristics and year of exposure. Subjects were classified according to age group. The significant difference based on One-way ANOVA was calculated for age groups at 95% confidence interval[1]. The comparisons were made for ventilatory capacities between each category and the values of FVC, FEV_1, PEFR, and FEF25-75 were compared for significance.

RESULTS

Houses characteristics

The houses characteristics such as kitchen type, kitchen ventilation, and stove type, type of fuel, roof and wall material among the population under study are given in the TABLE 1.

In rural and sub-urban area the kitchen type without partition was higher i.e. 38% and 32% respectively compared with other variables of the kitchen. In urban area separate kitchen exhibits was 42% which was higher than other variables and categories. Kitchen ventilation

TABLE 1 : Housing characteristics in the study area

Characteristics	Variable	Rural (*n-200)	Sub urban (*n-200)	Urban (*n-200)
Kitchen type	Without partition	38	32	21
	With partition	24	28	23
	Outdoor kitchen	17	21	14
	Separate kitchen	21	19	42
Kitchen ventilation	Poor	47	39	26
	Moderate	31	37	28
	Good	22	24	46
Stove type	Traditional three stone stove	32	27	19
	Chulla with mud & ridges	37	31	28
	LPG Gas	23	31	46
	Kerosene	8	11	7
Type of Fuel	Wood	28	26	21
	Agrowaste (Grass, Leaves, Trash, crop waste)	31	27	19
	LPG Gas	21	30	47
	Kerosene	11	9	8
	Dung	09	8	5
Roof material	Earthen	38	22	16
	Wood	16	24	14
	Metal sheet	27	31	28
	Cement concrete	19	23	42
Wall material	Earthen	42	32	23
	Wood & Mud	35	41	29
	Cement concrete	23	27	48

*n-Number of houses surveyed

in rural, sub-urban and urban area was poor in 47, 39 and 26% houses respectively. Stove type used in rural houses was traditional three stone stove in 32% and Chula in 37%. The use of LPG gas and kerosene was 23 and 8% householders in rural area. In urban area 46% houses used LPG gas followed by Chula and traditional stove with less percentage of kerosene.

Types of fuel used in rural houses were agrowaste followed by wood, LPG gas, kerosene and dung. In sub-urban area the fuel used was 30% LPG gas, 27% agrowaste, 26% wood, 9% kerosene and 8% dung. In urban area fuel used for cooking and heating was 47% LPG gas, 21% wood, 19% agrowaste, 8% kerosene, 5% dung. Roof material used in rural areas was 38% earthen, 27% metal sheet, 16% wood, and 19% cement concrete. In urban area the material used for roof was 42% cement concrete, 28% metal sheet, 16% earthen and 14% wood. The wall material used for rural houses was 42% earthen, 35% wood & mud and 23% cement concrete. In urban area households used the 48% cement concrete, 23% earthen and 29% wood & mud.

Indoor air environment

The general characteristics of the rural, sub-urban, and urban areas are shown in TABLE 2.

TABLE 2 : Demographic characteristics of target groups and indoor environmental quality

Sr. No.	General characters	Urban	Sub-urban	Rural
1	Temp.°C (n-200)	33±11 (25-41)	35±11 (29-43)	37±10 (30-44)
2	Humidity % (n-200)	54±28 (34-73)	49±18 (36-62)	47±16 (36-59)
3	Age in years (n-200)	41±30 (16-78)	46±42 (16-76)	44±39 (16-72)
4	Weight in Kgs (n-200)	55±37 (29-78)	54±32 (31-76)	52±33 (28-74)
5	Height in cms (n-200)	160±25 (142-178)	155±27 (136-175)	157±27 (138-176)
6	Dust concentrations in mg/m^3(n-200)	1.63±0.5 (0.78-1.98)	13.03±3.9 (9.47-18.34)	16.14±3.3 (13.67-21.90)

Note: The values are mean±SD of all samples. Values in parentheses show the range of parameter

The average temperature at the kitchen area ranged from 33 to 37°C. Average humidity observed was from 47 to 54%. Average age of the subjects under study was 44 years. The subjects selected for the study were ranged from 16 to 78 years. Average weight of the subjects was around 54Kgs and ranged from 28 to 78Kgs. Height among the subjects reported on an average of 157cms and ranged between 136 and 178. Dust concentrations at urban, sub-urban and rural houses were 1.63±0.5, 13.03±3.9, and 16.14±3.3mg/m^3 respectively.

Respiratory status

The data on pulmonary function tests of the rural, sub-urban and urban population was presented in TABLE 3.

The results indicate that the forced vital capacity (FVC) among the female subjects of rural areas was 61% which was lower than male (67%). Forced expiratory volume in one second (FEV_1) indicates 71% efficiency in female subject whereas male has 77% efficiency in rural areas. Similarly the lower efficiency of FEV_1 was observed in the sub-urban areas. Peak expi-

TABLE 3 : Pulmonary function tests (PFT's) with respect to gender in the target population

Category	Sex	FVC			FEV_1			PEFR			FEF 25-75			p-value
		EXP	OBS	%	EXP	OBS	%	EXP	OBS	%	EXP	OBS	%	
Rural	Female	2.02±0.35	1.24±0.35	61	1.63±0.3	1.15±0.41	71	5.56±0.86	4.08±1.27	73	2.82±0.48	2.31±1.04	82	0.04
	Male	3.15±0.49	4.22±0.55	67	2.57±0.48	3.98±0.56	77	8.18±1.26	8.97±1.98	75	5.36±0.68	4.98±1.51	93	
Sub-urban	Female	2.14±0.31	1.42±0.30	66	1.7±0.27	1.23±0.35	72	5.28±1.49	4.23±1.39	80	3.48±0.55	2.92±1.19	84	0.04
	Male	6.68±0.73	4.63±0.56	69	5.18±0.64	3.98±0.54	77	6.96±2.72	6.49±2.08	93	4.24±0.88	3.98±1.45	94	
Urban	Female	2.02±0.25	1.35±0.28	67	1.59±0.21	1.25±0.37	79	4.24±0.57	3.51±1.137	83	2.58±0.44	2.27±0.98	88	0.02
	Male	6.18±0.43	4.28±0.53	69	4.51±0.42	3.78±2.58	84	6.93±0.73	6.48±1.96	94	3.85±0.55	3.80±1.22	99	

Note: Overall difference is based on one-way ANOVA $p<0.04$, 0.04 and 0.02. The test was performed for comparison of observed values of pulmonary function test in rural, sub-urban and urban areas among male and female subjects, where F values in ANOVA are significant. Significant difference at $p<0.05$ by multiple comparison tests. *Male n-100, Female n-100

ratory flow volume (PEFR) resulted in 73% efficiency in female compare to 75% in male subjects in rural category. FEF25-75 observed in female was 82% whereas in male it was 93%. The one way ANOVA for the comparison between female and male shows p-value below 0.04.

Among the sub-urban subjects the values of FVC were 66 and 69% in female and male subjects respectively. FEV_1 values in the households were 72 and 77% for female and male. PEFR efficiency was observed 80 and 93% in female and male subjects'. The FEF25-75% in female and male subjects of sub-urban was 84 and 94%. The p-value is below 0.04 and shows significant difference between the female and male in sub-urban areas.

The values of FVC in the urban households were 67 and 69% whereas FEV_1 were 79 and 84% in the female and male subjects respectively. PEFR efficiency was observed 83 and 94% in female and male of urban areas. The FEF25-75 in female and male subjects of urban areas was around 88 and 99%. The p-value is below 0.02 and shows significant difference between the male and female of urban areas.

Ventilatory impairment

Ventilatory impairment data for households of rural, sub-urban and urban areas is presented in TABLE 4.

In rural areas 16 and 12% of female and male subjects shows the severe symptoms of air flow obstruction. The values of FVC for severe symptoms in sub-urban households were 11 and 14% whereas in urban 8 and 10% in male and female respectively. In urban subjects FVC value shows 20 and 40% subjects are in moderate range whereas 54 and 36% subjects having mild symptoms of air flow obstruction. In rural category 38 and 32 % male and female were in moderate range of air flow obstruction. As compared to the urban subjects, a rural and sub-urban subject shows moderate range of air flow obstruction. FVC values in the rural category were 22 and 24% in normal condition in male and female whereas 23 and 21 of sub-urban and 18 and 14% of subjects were normal.

The subjects of rural areas showed restrictive defects (FEV_1) values as 14 and 16% in male and female and 24 and 12% subjects in severe and normal category respectively. The FEV_1 value shows 34% and 44% subject's fall in moderate category in male and female respectively. 34% female subjects of sub-urban category falls in moderate category whereas only 26% of male in the same category. Restrictive defect values in sub-urban category were10 and 14% in male and female subjects. 8% of male and female each were having restrictive defect in urban category.

The asthmatic symptoms in the rural subjects having highest percentage (16 and 22%) of ventilatory impairment in severe range followed by 30 and 36% in moderate category of male and female respectively. Rests of the subjects were having mild to moderate impacts on the ventilatory capacities. In the sub-urban subjects PEFR values shows that 24 and 22% falls in normal category and only 14 and 20% fall in severe category in male and female. Majority of the group was covered under mild to moderate effect category. The Asthmatic symptoms in urban male and female subjects shows that having 22% and 30% in normal and 14 and 12% in severe category respectively. The PEFR values in urban were 26 and 30% in

TABLE 4 : Gender-wise ventilatory Impairment in the target population

Sr. No.	Lung status	Rural		Sub-urban		Urban	
		Male	Female	Male	Female	Male	Female
	Air flow obstruction						
1	Normal (FVC>80 %)	22	24	23	21	18	14
	Mild (FVC>60≤80 %)	28	28	32	25	54	36
	Moderate (FVC>40≤60 %)	38	32	34	40	20	40
	Severe (FVC≤40 %)	12	16	11	14	8	10
	Restrictive defect						
2	Normal (FEV1>80 %)	24	12	28	18	26	38
	Mild (FEV1>60≤80%)	28	28	36	34	42	34
	Moderate (FEV1>40≤60%)	34	44	26	34	24	20
	Severe (FEV1?40 %)	14	16	10	14	8	8
	PEFR asthmatic symptoms						
3	Normal (PEFR>80%)	20	26	24	22	22	30
	Mild (PEFR>60≤80%)	34	16	30	30	34	32
	Moderate (PEFR>40≤60%)	30	36	32	28	30	26
	Severe (PEFR≤40%)	16	22	14	20	14	12

*N=100 in both male and female subjects in each target groups

female and male in moderate category and 32 and 34% in mild category.

Respiratory symptoms

The symptoms of respiratory disease in the urban, sub-urban, and rural households are presented in TABLE 5.

In urban and sub-urban population 46 and 59% male and 57 and 76% female subjects reported difficulty in respiration. Difficulty in respiration was observed 66 and 86% in rural male & female subjects. Higher percentage of no difficulty in respiration was reported in male & female subjects in urban as compared to sub-urban and rural population. Pain in chest is having more prevalence (13 and 19%) in rural subjects whereas its prevalence was reduced in sub-urban (12 and 19%) and urban subjects (10 and 12%). Frequent coughing was reported by 38% female and 32% male in the category of rural areas. Sub-urban (28 and 33%) and urban (24 and 27%) subjects of both gender having less frequent coughing as compared to rural subjects. Irritation in throat is more prevalent in the rural category (female 29% and male 21%) as compared to sub-urban & urban subjects. The throat irritation was reported by 12% male and 18% female subjects whereas 19% male & 24% female in the sub-urban and urban subjects.

TABLE 5 : Prevalence of respiratory disease symptoms in the target groups under the study

Sr. No.	Particular	Percentage of prevailing symptoms					
1	Population category	Urban		Sub-urban		Rural	
2	Sex category	Male	Female	Male	Female	Male	Female
3	No difficulty in respiration	54	43	41	24	34	14
4	Difficulty in Respiration	46	57	59	76	66	86
5	Pain in chest	10	12	12	19	13	19
6	Frequent coughing	24	27	28	33	32	38
7	Irritation in throat	12	18	19	24	21	29

*N=100 in both male and female subjects in each target groups

DISCUSSION

The nature and levels of indoor air pollution is different in the developed and the developing world. There is growing evidences that poor air quality inside the homes poses a serious threat to human health. The study indicates that the rural population is exposed to high dose (16.14mg/m^3) of PM_{10}. Similar exposure of the rural population to the dust (8.5mg/m^3) in Pakistan[7]. In rural, sub-urban and urban sites, variation was observed in mass of PM_{10}. A study conducted in rural area of Tamil Nadu on exposure from cooking with biofuels revealed that PM_{10} ranged from 500-

2,000μg/m3 during a 2-h cooking period and was dependent on kitchen type and fuel use[4,5]. A large variation of concentration of particulate matter has been recorded during a 24-h cycle within the kitchen. Such variations were primarily due to the contribution from biofuels smoke inside the kitchen.

Forced vital capacity (FVC) among the female subjects of rural areas was lower than male subjects. Forced expiratory volume in one second (FEV_1) indicates reduced efficiency in female subject compared with male in rural, sub-urban, urban areas. Peak expiratory flow volume (PEFR) resulted in decreased efficiency in female compare to male subjects in each category. FEF25-75 observed in female was lower than male in all the category of the subjects. Among the female subjects large number shows moderate to severe air flow obstruction and restrictive defect than male subjects in each target groups. Moderate to severe asthmatic symptoms were observed in the female of rural area. In the female subjects more problems of respiratory symptoms such as pain in chest, frequent coughing and irritation in throat were observed in rural area.

CONCLUSION

The unhygienic conditions were observed during use of biomass fuel for cooking in rural areas. The study shows that higher dust concentration prevails in rural than urban and sub-urban houses. The respiratory symptoms in the female subjects in rural area showed decreased pulmonary efficiency. Forced Vital Capacity of the female and male subjects of the rural areas were less as compared to sub-urban and urban category. The result shows increase in ventilatory impairment in female as compare to male in each category. Reduction in pulmonary efficiency with increase in exposure to the pollutants was observed. Increased air flow obstruction is observed in the subjects of rural areas as compared to other target groups. Restrictive defect was observed to a great extent among the subjects of rural area than the other target groups. The statistical analysis shows significant difference for respiratory functions among all these groups. Difficulty in respiration, pain in chest, frequent coughing, and irritation in throat are most prevalent symptoms among the groups under study. Prevalence of asthmatic symptoms is more in the rural subjects. The authors suggest that gas and smokeless chulhas could be a better option for the rural population. Low economical condition and less availability of gas connection in rural area are the major retarding factors for use of liquefied natural gas.

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