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Assessment of indoor environmental impacts on human health (Case study: Glass city, Firozabad (India))

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ABSTRACT: The present study aims to analyze the existing indoor environmental conditions of Firozabad City along with its impact on people's health by going through the correlative index of indoor environment's determinant and different diseases, faced by the people. In order to measure spatial disparities, the statistical technique, i.e. the standard score additive model (Z- score), has been applied to develop a composite score for each set of indicators in order to arrive at the general environmental and health condition of the study area as a whole. The analysis reveals that high intensity of indoor pollution and disease are reported in peripheral and old parts of the city. Preventive measures, likely to have deleterious health effects and improve such harmful environmental conditions, should be adopted. Enhanced use of clean fuel and national uniform housing codes or guidelines that address factors, affecting indoor air quality, makes up the current need.

Keywords: correlative index, diseases, housing conditions, indoor air pollution.

INTRODUCTION

Exposure to indoor air pollution (IAP) is one of the major sources of health risks in fast developing countries like India. About 80% of the total Indian population, including 28% of urban inhabitants, currently rely on the combustion of biomass fuels for cooking activities (Census of India, 2011). In general, IAP has been ranked among top ten health risk factors in developing countries, which contributes to almost 2.6% of the global burden of diseases, 1.6 million pre-mature deaths per year, and about one million deaths below the age of five years old, according to the latest available estimates (Smith & Mehta, 2003; Balakrishnan et al., 2011). Nearly half of the world's population burns solid fuels (e.g. coal, biomass, and animal dung) as their principal household fuel for cooking, heating, and lighting. In 2001, it was estimated that IAP in these households was responsible for almost 2 million premature deaths, representing approximately 3% of the global burden of disease (Elliott et al., 2013). However, in urban areas, there are other reasons such as poor sanitation, generation of solid wastes, open land filling, burning of solid waste, inadequate housing, lack of awareness regarding toxicity of air pollutants emitting from various sources, and shortage of water supply, to result in the ill state of women and children (Bruce et al., 2000). Indoor Air Quality requires attention as it is related to the health and comfort of people who spend most of their time indoors. Heating, cooking,

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smoking, cleaning, as well as furnishings or building materials are important indoor sources of gaseous pollutants and particles (*de Gennaro et al., 2016)*, the impact of which is linked to the amount and hazard of the emitted pollutants, indoor activities, and poor ventilation qualities are responsible for high level of indoor RSPM and PAHs in rural houses in India (Gadkari & Pervez, 2008). However, far less attention has been paid to the IAP issues in urban areas, posing an equally important problem, since multiple sources of indoor air pollutants, apart from biomass fuel burning, co–exist with sources such as tobacco smoking in urban indoor areas. Some of the key factors, affecting the IAQ include (i) concentration of outdoor air pollutants, penetrating indoor environments, (ii) building materials such as asbestos, cement, wood preservatives, and volatile organic compounds, released from paints, glues, resins, polishing materials, perfumes, spray propellants, and cleaning agents, (iii) building characteristics such as air tightness and ventilation, (iv) building occupancy and living space, (v) equipment used within the buildings (e.g. photocopiers, printers, heaters, etc.), (vi) the customs, habits, and traditions of the residents, and (vii) economic status of the occupants (Kumar, 2011).

Based on the literature review, mentioned above, the present study has attempted to evaluate the indoor air quality and disease profile at the household level in different wards of Firozabad City, India. It has also been tried to assess the relation between pollution intensity and the most-occurring diseases at household level.

MATERIALS AND METHODS

Firozabad, the glass city, is located in north central India, in the western Uttar Pradesh state, 40 km off Agra and 218 km off Delhi at the northern edge of the Deccan Plateau, at 27° 15' N and 78° 42' E (Fig. 1).

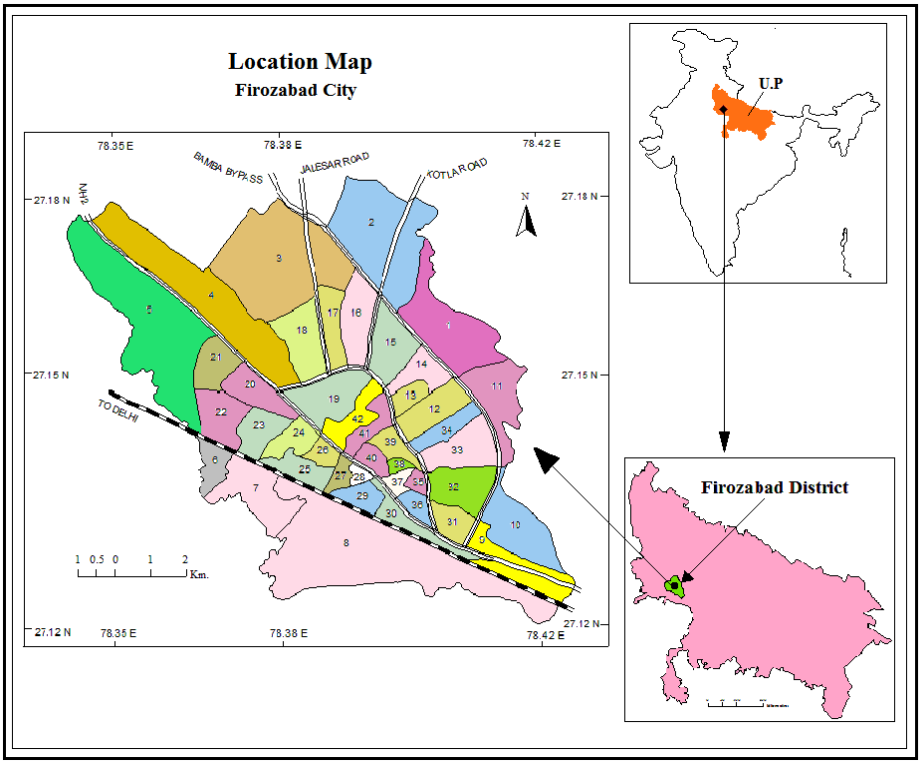

Fig. 1. Study area map
Source: Nagar Palika Parishad and water works, Firozabad

Firozabad is spread in an area of 21.35 sq.km, bounded by River Yamuna from southern and western side with a population of 603,797, according to 2011 census. It has an average elevation of 164 meters (540 ft). The city has got the monopoly of glass production, responsible for 70% of the total glass production in India, due to which it is also called as *Suhag Nagri.*

The study is entirely based on primary source of data, obtained from a comprehensive survey conducted from May 2012 to October 2013 by means of a questionnaire. Data is collected from 42 wards through purposive random sampling method. In total, 3050 heads of the household have been interviewed from entire wards, forming 3% of the total households of each ward. The strategy, adopted for household selection, has been purposive random, taking into consideration the houses, where the compressor work on bangle, as well as those near *Pakkai Bhattis* and beyond the range of 15-20 meters. The city is an industrial area, apart from large industrial units, where only glass is made from raw material. The entire city is netted with household industry, acting as a supporting unit for final production to marketing of the glass and bangles. Type and location of the house has also been taken into considerations. The questionnaires, used for the study, contained questions on personal and housing characteristics (sex, age, smoking habit, family income, housing condition, cooking fuel, industrial unit in colony, smoke coming from outside, ventilation, etc.) and health profile (conjunctivitis, rhinitis with seasonal changes, history of cough, sore throat, rashes or itching on skin, history of any post nasal drip, wheezing, chest tightness, sputum, breathlessness, doctor-diagnosed asthma and tuberculosis, and any systematic complaints such as headache, fever, nausea, etc.). The data collected from the field survey were organized, moderated, tabulated, and analyzed with the help of suitable statistical techniques and represented in graphs, diagrams and maps. Two methods have been used to examine the household environmental quality and its impact on the residents. To establish a relation between household environmental quality and human health, the *Karl Pearson's Coefficient of Correlation technique* has been employed. In order to measure spatial variations, the statistical technique, i.e. *Z score*, has been used to develop a *composite score* for each set of indicators in order to arrive at the general housing and environmental condition of the study area as a whole. It is a linear transformation of the original data in such a way that its mean becomes zero and its standard deviation, one. For observation 'i' on any variable, the standard score is obtained with the help of the following formula:

$$z_i = \frac{X_i - \overline{X_i}}{\partial_i (SD)}$$

where,

Zi= denotes standard score of i^{th} Variable

Xi= Original Value of i^{th} Variable

$\overline{X_i}$ = Mean of i^{th} Variable

∂ = Standard deviation of i^{th} Variable

The composite score is obtained with the help of the following formula:

$$CS = \frac{\sum z_{ij}}{N}$$

where,

CS = composite Mean Z- Score

Zij = Standard Score of i^{th} Variable at j^{th} unit of study

N = No. of Variables.

RESULTS AND DISCUSSION

Indoor air pollution in sampled houses of different wards has been analyzed in terms of the sources, types, and intensity of pollution. It has been found that out of the total sampled households, 18.38% used to cook food in multipurpose rooms. Housing conditions have a direct influence on health; especially in terms of indoor air pollution and sanitation-related diseases.

As far as the nature of open space in the house is concerned, 46.65% of the respondents spoke of no open area. Ventilation is one of the important components to determine the quality of indoor air, being a complex process that ultimately supplies and removes air from inside a closed structure. Indoor air pollution has been identified as a major health risk, highly associated with poor ventilation. More than half of the sampled households (66.20%) reported that they did not have proper ventilation in their houses. Many health problems are associated with overcrowding or congestion, basically because of the small living space areas and more household members. A total of 60.04% of the households claimed congestion in their houses that ultimately affects the health and hygiene of an individual. Concerning the floor space per person in the sleeping rooms, it has been observed that out of the total sample, the sleeping area of 33.79% was less than 10 sq. ft. per person.

Regarding the fuel, used for cooking in different wards of the city (Table 1), 36.57% of the sampled households mainly relied on conventional fuels such as kerosene, coal, dung cake, sawdust, and dry leaves twigs that create lots of smoke. The outer parts of the city have been observed to heavily rely on bio-fuels (70.25%) especially, Kashmirigate, Tapa khurd, Labour colony, Ramgadh, Humayunpur, Santnagar, Asfabad, Lalpur, Rehna, Tade wali Bagiya, and Habib ganj. Another major source of pollution, along with cooking on biofules, is coal and kerosene, used when straightening (sadai) and joining (jodai) the bangles, which are done in the houses and due to poor ventilation, the smoke remains there for a longer duration.

Table 1. Air Pollution in Respondents House (%) in Firozabad City

Categories	Multiuse rooms	Lack of open space	Not Proper Ventilation	Low per head space	Use of Bio fuel	Congestion	Smoke remain inside house	Smoking in house
High	9.86	24.67	40.26	14.25	13.75	33.11	24.05	29.59
Medium	15.80	44.51	70.95	35.30	33.58	66.28	43.91	57.09
Low	27.40	70.17	86.28	58.24	70.25	86.41	66.15	79.99
Total	18.38	46.65	66.20	33.79	36.57	60.04	43.75	56.21

Source: Based on field survey 2012-2013.

Indoor air pollution is a major health concern in today's globalized world. Health effects from exposure to indoor air pollutants may be experienced soon after exposure or even in some cases after many months or years (ICMR Bulletin, 2001). To examine the impact of indoor air pollution on human health, two variables have been selected. They are X and Y that refer to indoor air pollutants and associated diseases as independent and dependent variables, respectively. Nine variables of major sources of indoor air pollution and eight diseases, taken into consideration, are as follows:

X1	Congestion	Y1	sore throat
X2	multiuse room	Y2	allergy
X3	lack of open space in house	Y3	asthma
X4	not proper ventilation in house	Y4	bronchitis
X5	low per head space	Y5	tuberculosis
X6	smoke coming from outside	Y6	pneumonia
X7	biomass fuel	Y7	conjunctivitis
X8	smoke remains inside house	Y8	rhinitis
X9	smoking in house		

Table 2. Most Frequently Reported Diseases in Respondents' Families (%) in Firozabad City

Categories	Sore throat	Allergy	Asthma	Bronchitis	Tuberculosis	Pneumonia	Conjunctivitis	Rhinitis
High	18.90	25.17	13.80	19.93	8.36	16.98	31.64	9.81
Medium	34.56	43.79	23.28	34.11	17.72	31.57	44.00	18.94
Low	51.22	57.64	36.19	50.84	29.43	46.64	56.89	30.28
Total	35.24	41.64	24.26	34.62	19.17	30.66	44.49	19.09

Source: Based on field survey 2012-2013.

The analysis reveals that conjunctivitis has been reported by largest number (44.49%) of the respondents (Table 2), followed by Allergy (41.64%), Sore throat (35.24%), Bronchitis (34.62%), Pneumonia (30.66%), Asthma (24.26%), Tuberculosis (19.17%), and Rhinitis (19.09%).

Table 3 shows that all the variables of indoor air pollution are positively correlated to probable diseases. Their correlation is significant at 1% level with the exception of low per head space availability and bronchitis, which are significant at the 5% level. Though their relation is significant at 1% and 5% level, they are correlated with varying degrees of 'r' value.

Sore throat is a common problem that comes under acute respiratory infection (ARI). It is an upper respiratory tract infection, which include common cold, pharyngitis, and otitis media (Park, 2005). The diseases, reported by 51.22% of the respondents, come under high category, followed by medium category (34.56%), and low category (18.90%). The diseases show strong positive correlation with smoking inside the house (r=+0.906) and lack of open space in the house (r=+0.901).

Allergy includes rashes on skin, itching on skin, and respiratory allergies (shortness of breath, sneezing, breathlessness, suffocation, and morning cough) which are recorded by 41.64% (Table 2) of the respondents (under high 57.64%, medium 43.79% and low 25.17% category). It shows positive correlation (Table 3) with the houses without proper ventilation (r=+0.925), smoking in the house (r=+0.856), lack of open space in the house (r=+0.843), and smoke remaining inside the house for longer period (r=+0.835).

Asthma is an inflammatory disease of the lungs, which is a chronic condition, involving the respiratory system in which the airways of the lungs occasionally constrict, become inflamed, and are lined with excessive amounts of mucus, often in response to one or more stimuli. These episodes may be triggered by exposure to an environmental stimulant like an allergen, environmental tobacco smoke, cold or warm air, perfume, pet dander, moist air, exercise or exertion, or emotional stress. In children, the most common triggers are viral illnesses such as the ones causing the common cold (Zhao et al., 2002). This airway narrowing causes symptoms such as wheezing, shortness of breath, chest tightness, and coughing. It is positively correlated with the lack of open space in the house (r=+0.794), not proper ventilation (r=+0.791), smoking inside the house (r=+0.756), and smoke remain inside the house (r=+0.744).

Bronchitis is a lower respiratory tract infection with a combination of symptoms and signs, including sputum, breathlessness, and duration of symptoms with any seasonal variation. A positive correlation has been found with the smoke remaining inside the house (r=+0.759), smoking inside the house (r=+0.740), and lack of proper ventilation in the house (r=+0.719).

Tuberculosis is caused through infection with "*Mycobacterium tuberculosis*" the *tubercle bacillus*, which can affect almost any tissue or organ of the body, the most common seat of the diseases being the lungs. Active pulmonary tuberculosis is

Table 3. Relation between Indoor Air Pollution (Independent Variables) and Occurrences of Diseases (Dependent Variables) in the Respondents Family

	Correlations							
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**
X1	.720**	.714**	.592**	.529**	.569**	.725**	.789**	.686**
X2	.834**	.715**	.723**	.577**	.744**	.658**	.614**	.761**
X3	.901**	.843**	.794**	.596**	.768**	.702**	.719**	.790**
X4	.857**	.925**	.791**	.719**	.838**	.805**	.863**	.831**
X5	.635**	.630**	.667**	.336*	.667**	.619**	.608**	.652**
X6	.503**	.478**	.439**	.448**	.472**	.518**	.432**	.420**
X7	.559**	.644**	.437**	.673**	.477**	.523**	.624**	.511**
X8	.803**	.835**	.744**	.759**	.824**	.678**	.726**	.786**
X9	.906**	.856**	.756**	.740**	.816**	.776**	.791**	.837**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Calculated from data collected from field survey (2012-2013).

relentlessly chronic and, if left untreated, leads to progressive destruction of lung tissue (Mishra *et al.*, 2002). It is correlated with lack of proper ventilation in the house (r=+0.838), smoke remaining inside the house (r=+0.824), and smoking in the house (r=+0.816).

Pneumonia is a lower respiratory tract infection, leading to limited flow of air to and from the lungs causing shortness of breath (Rabe et al., 2007). It is positively correlated with all the variables but shows strong correlation with lack of proper ventilation in house (r=+0.805), smoking in house (r=+0.776), and congestion (r=+0.725).

The exposure of eyes to the emanating smoke causes eye irritation and other related symptoms, including nose and throat irritation, coughing, and wheezing, which are signs of sick building syndromes (SBSs) commonly due to inadequate ventilation and contaminants from various sources.

Conjunctivitis is related to eye watering and eye itching due to eyes' exposure to radiating smoke containing toxins. It is positively correlated with all the variables, showing strong correlation with lack of proper ventilation (r=+0.863), smoking in house (r=+0.791), congestion (r=+0.789), Biomass fuel (r=+0.624), and multiuse room (r=+0.614).

Rhinitis is irritation and inflammation of some internal areas of the nose, and is caused by bacteria, viruses, and irritants. It is strongly correlated with smoking in house (r=+0.837), not proper ventilation (r=+0.831), lack of open space in house (r=+0.790), and smoke remaining inside the house (r=+0.786).

In order to find out the relation between the intensity of pollution and the intensity of diseases, composite mean Z-score index has been developed. Figure 2 shows the spatial analysis of the intensity of indoor air pollution and associated diseases, clearly revealing that under high category of intensity of indoor pollution, 33.33% of city wards (Table 4) come, consisting of 14 wards, while medium and low consist of 16 (38.10%) and 12 (28.57%) wards, respectively. As far as intensity of diseases is concerned, under high category 13 wards comprising 30.95% of total wards of the city comes, while medium and low category consists of 15 (35.71%) and 14 (33.33%) wards, respectively (Table 5).

Spatial analysis (Fig. 2) reveals that high intensity of indoor pollution and high intensity of diseases are found in peripheral and old parts of the city as well as the industrial areas, such as Dholpura, Joshiyan, Asfabad, Lalpur, Habib Ganj, Tadewali Bagiya, Sant Nagar,Ashraf Ganj, Galib Nagar, Ramgadh, Hymaunpur, Karbala, Bagiya Mohalla, Rehna, and Rahi Nagar, since most of these areas are occupied by the laborers and low-income groups, mostly

engaged in bangle straightening, joining, and designing which is still carried out at household level on coal and kerosene. Apart from this compressor work inside the house for polishing the bangles in every tenth house, it is very much prevalent in these areas having very compact and ill ventilated houses. Some areas like Bagiya Mohalla, Sant Nagar, Kashmiri Gate, Humayunpur and Joshiyan etc. are slums and so congested that there is no space for fresh air to replace the intensive room air, as in these wards bangle and glass ware factories are still emitting lots of smoke from industries as well as generator sets, installed there.

The peripheral parts of the city, though covering a large area and having high space and houses, comes under medium category of intensity of pollution and intensity of diseases, while some wards have high intensity of pollution but medium intensity of diseases like Tapa Khurd, Rahi Nagar, Galib Nagar, and Karbala, owing to fairly good

Table 4. Intensity of Indoor Air Pollution in Firozabad City

Category	Ranges	Total Wards	per cent of Total wards
High	Above 0.41	14	33.33
Medium	-0.41 – 0.41	16	38.10
Low	Below -0.41	12	28.57

Source: Based on field survey 2012-2013.

Table 5. Intensity of Diseases in Firozabad City

Category	Ranges	Total Wards	per cent of Total wards
High	Above 0.44	13	30.95
Medium	-0.44 – 0.44	15	35.71
Low	Below -0.44	14	33.33

Source: Based on field survey 2012-2013.

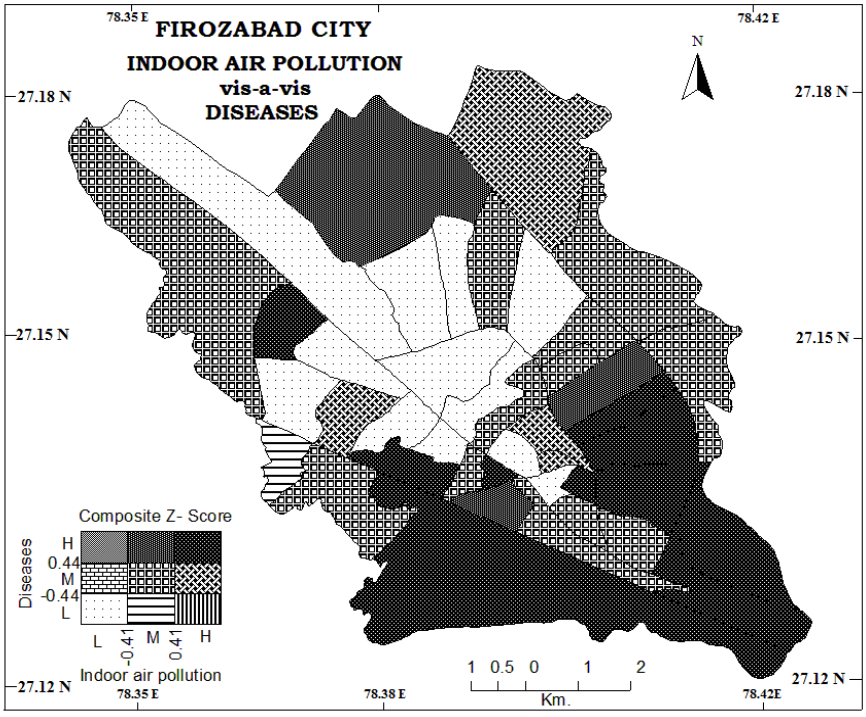

Fig. 2. Relation between intensity of indoor pollution and intensity of diseases

space and less compactness as they are inhabited by medium- and high-income groups. As far as the intensity of pollution is concerned, it is due to the smoke coming from outside in *Pakai Bhatties* and running inside the wards and neighborhoods. In the peripheral areas, use of fuel for cooking is bio-fuel like cow dung, wood, saw dust, dry leaves, etc. which emits large amounts of smoke for long time. Medium Intensity of pollution and low incidence of disease is found in only one ward, i.e. Labour Colony, because this ward has existed older, where railway quarters and other related government residential are present with a low density of population. The reported pollution is due to less ventilated quarters and smoke from outside due to vehicles and railway, but thanks to the education and awareness, regarding sanitation and associated problems, the low intensity of diseases has been observed there.

Low intensity of pollution and low intensity of diseases is found in 12 wards such as Jain Nagar, Saraswati Nagar, Araya Nagar, Bodh Ashram, Nagla Karan Singh, Chaturvedi Compound, Mohammadpur, Hajipura, Suhag Nagar, MhavirNagar, Nai Basti, and Gherkhokhal as these areas are occupied by very-high- to high-income groups of the population with high standards of living, having spacious houses. Apart from high-class people (industrialists and businessmen) most of the wards are newly developed, having low to medium density of population (Suhag Nagar, Jain Nagar, Mahavir nagar, Araya Nagar, etc.) except Hajipura and Gherkhokhal, for these are old parts of the city and Muslim-dominated, less willing to move out due to various reasons, like kith and kin, paternal house, and social security.

CONCLUSION

After foregoing the discussion, it has become clear that indoor air pollution is a major problem which has been prevailing in the south-east to north peripheral and old central wards of the city. Regarding the relation between indoor environmental conditions and human health, diseases associated with poor indoor air quality are mainly observed in three quarters of the city, basically because of the unique characteristic of glass and bangle manufacturing for which Firozabad is renowned, being a labor-intensive work, ue to which a large accumulation of skilled and unskilled labors from different parts of the state as well as country have come and due to the low income, low status, and poor conditions, live in very unhygienic and unhealthy conditions. In spite of living inside the municipal boundaries, they too are ignored by the administration. Central part of the city is the commercial and traffic-congested area where RSPM and SPM have been recorded beyond the prescribed limit, causing different respiratory diseases. Medium and low intensities of diseases have also been observed in few wards, yet the situation is comparatively better as these are newer parts of the city and have been developed in a planned manner. Therefore adequate home ventilation is recommended particularly where wood, coal, cow dung, and dry leaves are used for cooking as well as kerosene and coal for bangle work, as these fuels emit smoke with toxicants and particulate matter; furthermore, for quick and efficient removal of fumes and smoke inside the house, it is important to improve cross ventilation by increasing the number of windows in the houses. Moreover, developing and enforcing housing guidelines and codes, implementing "Healthy Homes" programs to improve indoor environmental quality is also a current requirement. Also it is needed to generate people awareness, regarding the adverse impacts of indoor air pollution, and encourage changes in the habits (house cleaning, smoking, etc.) in order to improve the quality of home environment.

Indoor air pollution has a major impact on health. Rapid urbanization, globalization, and increasing population has led to a crisis, but

there is much emphasis on the environment. Hence, strategic actions should be taken by all sectors, otherwise the problem will worsen human health of humans and the problem will be harder in case of poor and vulnerable groups of the population. There is a need to address the problems differently. There are ways to iron out the situation and make women's time in the kitchen healthy and pleasurable. Such interventions can occur on many fronts which include:

- Clean and efficient cooking fuel (LPG, electricity),
- Improving cooking devices (stoves) to provide more heat, less smoke, and less fuel consumption,
- Improving living environment (ventilation through doors and windows, separate kitchen),
- Behavioral change (spending less time in the kitchen ,fuel drying ,using pot lids, proper maintenance of the stoves , and keeping children away from smoke)
- And *Awareness* towards ill health effects of indoor air pollution and making some standards for indoor pollutants.

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