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Health Impacts of Indoor Air Pollution of PM_{10} Size from Household Cooking Activities

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Abstract—*This paper throws light on household cooking related exposures and level of indoor air pollutants (particulate matter and gaseous pollutants- CO, CO_2, SO_2, NO, NO_2) in different exposure area from the different types of cooking fuels used. Still the prevalence of biomass fuels exists in Indian households, combustion of which releases higher levels of solid and gaseous pollutants during the cooking hours. The indoor air pollutants (SPM, CO, CO_2, SO_2, NO, NO_2) were measured with handy samplers with different types of cooking fuels (biomass and LPG). For this purpose the indoor air quality of 50 randomly selected households were monitored. The results suggests that average concentration of SPM (322.86 µg/m^3 for PM_{10}) and gaseous pollutants (CO-3.34 ppm, CO_2- 509.71 ppm, SO_2-0.07 ppm, NO-0.10 ppm, NO_2-0.03 ppm) were highest during cooking hours with biofuels in different cooking places. Thus, not only the women who are involved in cooking suffer from the various ill effects, but also other family members who are inside the house during cooking hours also face exposures. The recorded SPM (130.41 µg/m^3 for PM_{10}) and gaseous pollutants (CO-0.90 ppm, CO_2-398.71 ppm, SO_2-0.02 ppm, NO-0.04 ppm, NO_2-0.02 ppm) in LPG using households were lower as compared to biomass fuel using households. Due to the LPG efficiency the time involved in cooking is also low leading to less exposure to the pollutants released.*

Keywords*: PM_{10}. SPM. Biomass. Gaseous pollutant. Household cooking fuel. Health.*

1. INTRODUCTION

Atmospheric pollution is related with contagion of air or imbalance in the composition of air, while 'indoor air pollution can be demarcated as the sum of attributes of indoor atmosphere that affects a person's health and well-being'. In most of the developed the important pollutants are volatile organic compounds, radon, heavy metals, asbestos, mites, pesticides, animal dander, moulds and tobacco smoke. However, in developing countries, the most important indoor pollutants are the burning products of unrefined solid biomass fuels used by the poor urban and rural folk for heating and cooking. One of the major causes of the indoor air pollution is burning of cooking fuel (such as LPG, animal dung, wood, kerosene, agricultural residues, coal, etc.). Even today one half of the world's population, 95 percent in poor countries and more than 90 percent households of India still rely on solid fuels including biomass fuels. Biomass fuel, refers to a vegetation or animal based material deliberately burned by humans and wood is the most common biofuel, but use of dung and harvest residues is also used frequently [1].

It has been estimated that 50 times more noxious pollutants is released by unprocessed solid fuels than gas [2]. The efficiency Traditional fuels are characterized by low combustion efficiency that lead to huge emission of suspended particles and poisonous gases. The stoves or chulhas (u shaped open stoves made of bricks and mud) used for cooking purpose are not energy efficient in which the fuels are not completely burned. The incomplete combustion releases hundreds of complex toxic pollutants hazardous to health. Among these health damaging pollutants, toxic and irritant gases, the most important include PM, CO, NO_2, SO_2, HCHO and carcinogens for example benzo (0) pyrene and benzene [3]. The exposure to indoor smoke is particularly high among women and children because women spend responsible for family cooking and children below the age of five there most of the time with their mothers while they are engaged in cooking. Women generally begin regular cooking or start assisting in cooking around the age of 12 to 15 which leads to longer period of exposure to pollutants. Women spend between 3 to 7 hours per day near the stove for cooking food [4] (Singh, 2010). Due to customary involvement in the cooking women's exposure is very much higher than men's and many times the young ones are carried on mother's backs or on laps while cooking and thus they spend many hours breathing toxic pollutants.

Indoor Air Quality (IAQ) is one of the complex issues than any of the other environmental issues. Researchers indicate the presence of more than 900 contaminants in indoor air depending on different operational activities. The most important identified indoor air pollutants are polycyclic aromatic hydrocarbons (PAH), sulphur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO, NO_2), particulate matter etc. The sources of these pollutants are innumerable, such as, building materials used, carpets, furniture, smoking indoors, cooking fuels used, heating, cleaning etc., but the most important identified source by WHO is cooking with solid fuels.

Despite adverse health effects of indoor air pollution, this complex problem is not highlighted and discussed. Most sources of air pollutants normally monitored outdoors as according to the National Air Quality standard and very little is known about air pollution indoors [5]. Moreover, from combustion of traditional fuels the toxic pollutants released has been implicated and are risk for most respiratory diseases (such as tuberculosis, asthma, acute respiratory infections, chronic obstructive pulmonary diseases, etc.), , cancers, adverse pregnancy outcomes, eye problems, accidental problems, etc., particularly among women who are usually regarded as responsible for household work management and cooking in Indian cultural values.

Objectives

- Monitoring of indoor air pollutants (PM_{10}) and gaseous (CO, CO_2, SO_2, NO, NO_2)
- Identifying risk factors associated with indoor air pollution
- Identifying vulnerable women/households and the vulnerable areas of Jamshedpur City for future planning.
- Type of household energy used

2. EXPERIMENTAL

2.1 Study area

Tata Nagar is 86º04' to 86º54' east Longitude and 22º12' to 23º01' North latitude. It has an average elevation of 40 meters (131 feet). The city is situated 1400 km from New Delhi and a little less than 300 km north-west of Kolkata on the(NH-33) and Eastern Railway. The chief rivers are the swarnrekha and Kharkai. Tata Nagar is located in the south east region of Jharkhand. The city is located in the Chhota Nagpur plateau and covers an area of 3533 km^2. Sampling site is close to state highway Jamshedpur Kandra road, Godowns of Food Corporation of India, hotels, bakeries and Adityapur railway station also exist in the vicinity of the sampling area.

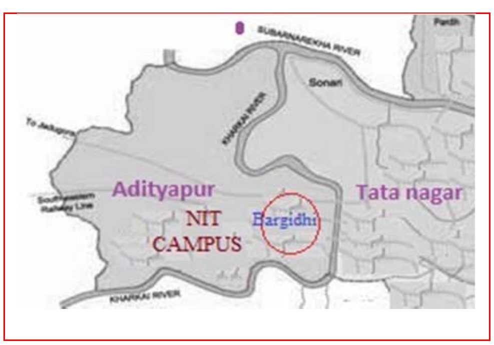

Fig. 1: Diagram of sampling sites location

Tata Nagar is one of the major industrial centres of Eastern India. It houses companies like Tata Steel, TCE, Lafarge, Tata Motors, BOC Gases, Tata Power, Cement, Telcon, Praxair, TCS, Timken, TRF, Tinplate and many more. It homes to one of the largest industrial zones of India known as Adityapur which houses more than 1,200 small and medium scale industries and has an SEZ named AIDA in the Adityapur. The details of sampling sites for the collection of PM_{10} are shown in Fig. 1

2.2 For indoor PM

Monitoring was carried out Chula at verandah with different usages of cooking fuel to diagnose the indoor air quality (IAQ) and to find out the concentration of suspended PM_{10}. This monitoring was carried out with the help of the handy sampler in the month of May, 2015. For the purpose of sampling, household's kitchen using biomass fuels and LPG fuel in chulhas were selected (chulhas in veranda). The pollutant monitoring of PM_{10} was performed 1/2 hour before cooking and two and half hour during cooking. The concentration of PM_{10} was averaged over and was recorded at 5 minute intervals. For the purpose of monitoring of suspended PM_{10}, a handy sampler "Portable GRIMM Dust Monitor Series 1.109" (Grimm Aerosol technic; Doff strabe 9; 83404 Airing Germany) was used. The operational characteristics of GRIMM is shown in table 1

Table 1: Operational characteristics of portable GRIMM dust monitor series 1.109.

Measuring principle	900 light scattering
Self-test	Automatically after every start
Sample flow rate	1.2 l/min ±5% constant with controller
Sample air filter	47 mm PTFE- round filter

2.3 For gaseous pollutants

Monitoring was carried out to measure the concentration of indoor gaseous pollutants with special emphasis on the measurement of emissions from the energy used for cooking. The levels of concentration of CO_2, CO, SO_2, oxides of NO, NO_2 were monitored. This monitoring was carried out with the help of the handy sampler in the month of May, 2015. The levels of pollutants released through the combustion of different fuels were assessed from 6.30 am to 6.30 pm for the houses using biomass fuels and 6.30 am to 8.30 pm for the houses using LPG stoves. For the monitoring of indoor gaseous pollutants (CO_2, CO, SO_2, NO, NO_2), handy samplers were used having separate sensors for sensing the concentration of each type of pollutant. The indoor gaseous pollutants like CO, SO_2, NO, NO_2 were measured by portable YES-205 multigas monitor (Young Environmental System Inc. Vantage way, Delta, BC, Canada). The concentration of CO_2 was measured by a portable YES-206 Falcon IAQ monitor (Young Environmental System Inc. 140-8771 Douglas St. Richmon, B.C V6X1V2 Canada). The self-test time for data was set in the interval of 5 minutes each but averaged hourly; data were calculated for whole day working hour in different types of kitchen with different fuel use.

3. RESULTS AND DISCUSSION

The United States Environmental Protection Agency [6] standard for an acceptable annual 24-hour average of PM_{10} is 150 $\mu g/m^3$, and they state that this level should not be exceeded more than once per year.

3.1 Biomass cooking fuel

3.1.1 Chulla in verandah

Fig. 2 shows the average daily PM_{10} concentration of 162.98 $\mu g/m^3$ just before ½ of cooking. During this ½ hour period the peak concentration recorded was 256.3 $\mu g/m^3$, while the minimum was 79.9 $\mu g/m^3$. The average daily concentration of SPM during cooking hour ranged from 264.81 $\mu g/m^3$, of which, maximum value found was 523.5 $\mu g/m^3$ while the minimum was 133.5 $\mu g/m^3$. The peak values during cooking time were observed either when the biomass fuel was found to be moist or when the fire in chulla is blown with mouth or blow-pipe for more heat.

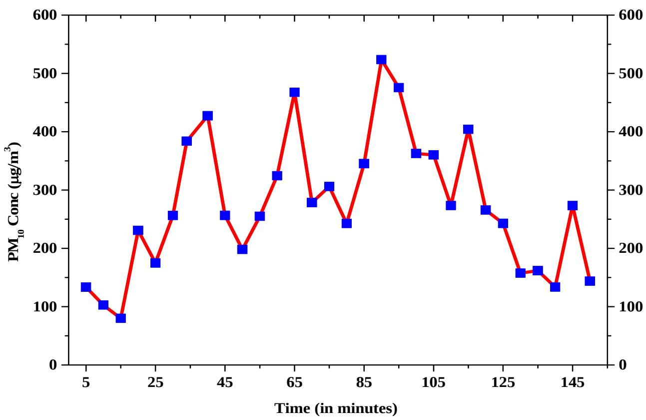

Fig. 2: Average daily concentration of PM_{10} using biomass fuel in Verandah

3.2 LPG cooking fuel

3.2.1 Chulla in verandah

Fig. 3 shows the average daily concentration of PM_{10} in and around cooking place in the verandah. The recorded observed average daily concentration of PM_{10} in non-cooking hours was 113.32 $\mu g/m^3$ of which the peak value recorded was 125.5 $\mu g/m^3$ while the minimum recorded value was 102.7 $\mu g/m^3$. The observed average daily concentration of PM_{10} in cooking hours was recorded 167.70 $\mu g/m^3$ of which the peak value recorded was 378.8 $\mu g/m^3$ while the minimum recorded value was 105.2 $\mu g/m^3$. Here again, it was observed that concentration of PM_{10} was higher during cooking hours than in non-cooking hour.

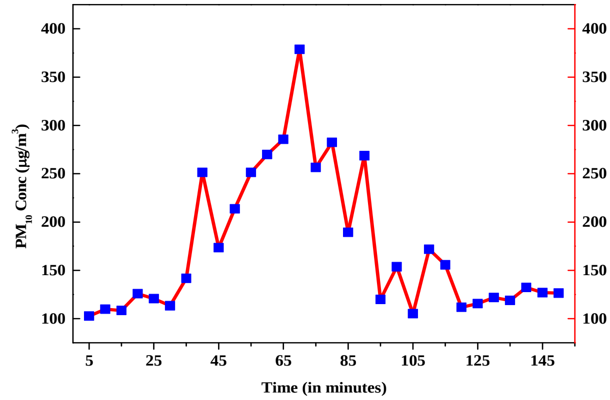

Fig. 3: Average daily concentration of PM_{10} using LPG fuel in Verandah

3.3 Gaseous pollutants

3.3.1 Biomass fuels

Fig. 4.1, 4.2, 4.3, & 4.4 are showing the concentration of gaseous pollutants (CO, CO_2, SO_2, NO, NO_2) around cooking, place during the working hours (including cooking hours) inside the house in the month of May 2015. The average daily concentrations of CO, CO_2, SO_2, NO, NO_2 were recorded to be 2.65 ppm, 492.00 ppm, 0.06 ppm, 0.08 ppm, 0.02 ppm. Of these recorded values of the whole day working hours, the maximum recorded values were, 7.3 ppm, 676.00 ppm, 0.15 ppm, 0.16 ppm, 0.06 ppm and the minimum recorded values were, 0.21 ppm, 289.00 ppm, 0.00 ppm, 0.01 ppm, 0.00 ppm of CO, CO_2, SO_2, NO, NO_2. The higher values of gaseous pollutants during the whole day recorded concentration were observed in morning, day time and in the evening i.e. all the highest values were recorded during the cooking hours while in non-cooking hours the lower concentration of gaseous pollutants were recorded. The highest concentrations were observed at the time of ignition of fire in chulhas when the fire in chulhas was blown with mouth or blow pipe for more heat. At this time the concentration of gaseous pollutants was higher due to emitted smoke and when the smoke dissipated the concentration of all these pollutants declined.

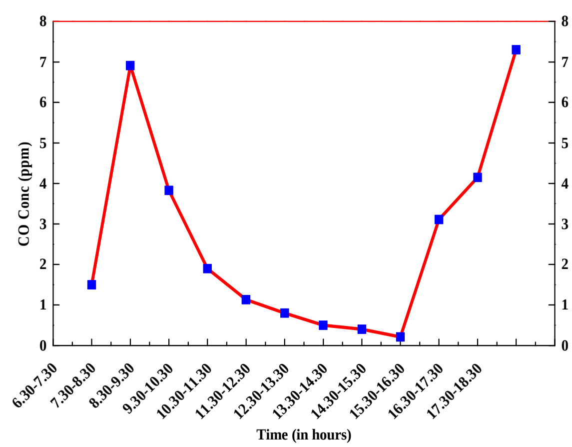

Fig. 4.1: Variation in concentration of CO using biomass fuel

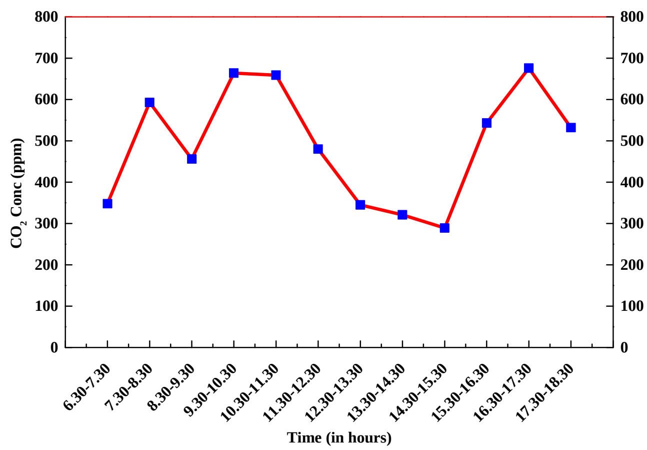

Fig. 4.2Variation in concentration of CO_2 using biomass fuel

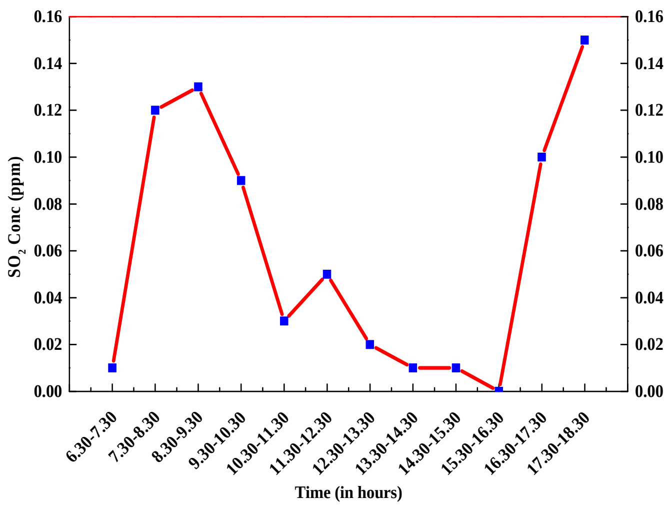

Fig. 4.3: Variation in concentration of SO_2 using biomass fuel

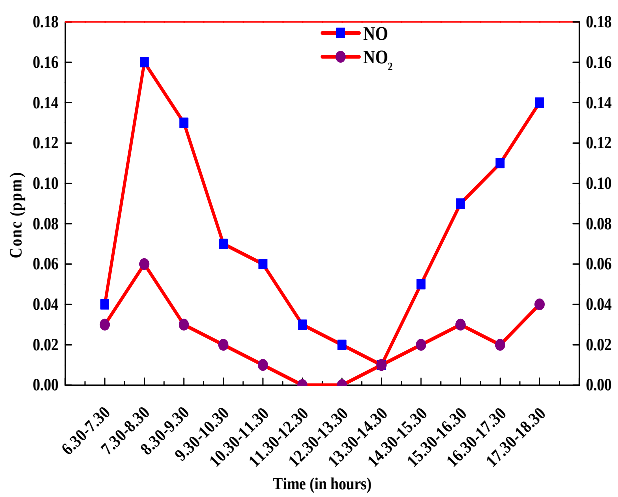

Fig. 4.4: Variation in concentration of NO & NO_2 using biomass fuel

3.3.2 LPG as cooking fuel

Fig. 5.1, 5.2, 5.3 & 5.4 are showing the concentration of common gaseous pollutants (CO, CO_2, SO_2, NO, NO_2) in the kitchen during the working hours (including cooking hours) inside the house. The average daily concentrations of CO, CO_2, SO_2, NO, NO_2 were recorded to be 0.89 ppm, 395.71 ppm, 0.02 ppm, 0.04 ppm and 0.02 ppm. During the monitoring hours, the maximum recorded concentrations of gaseous pollutants were, 1.7 ppm, 556.00 ppm, 0.06 ppm, 0.07 ppm, 0.04 ppm and the minimum recorded values were, 0.2 ppm, 234.00 ppm, 0.00 ppm, 0.01 ppm, 0.00 ppm of CO, CO_2, SO_2, NO, NO_2. The highest concentrations of gaseous pollutants during the whole day monitoring were observed little higher in morning, day time and in the evening i.e., during the cooking hours while in non-cooking hours the lower concentration of gaseous pollutants were recorded.

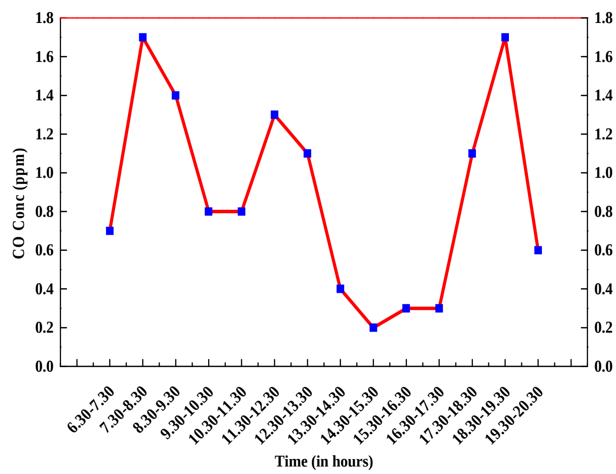

Fig. 5.1: Variation in concentration of CO using LPG fuel

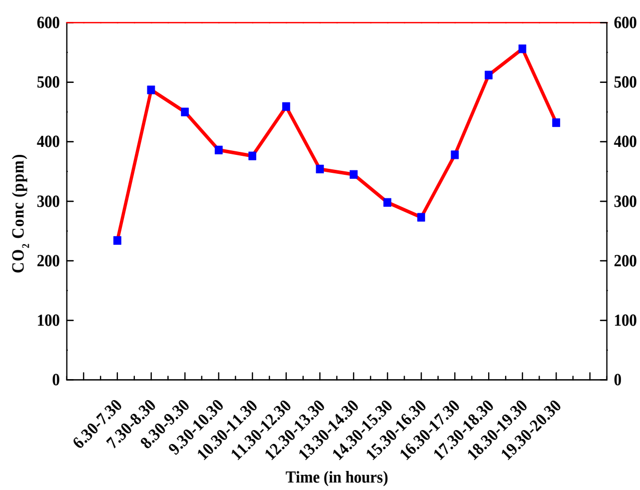

Fig. 5.2: Variation in concentration of CO_2 using LPG fuel

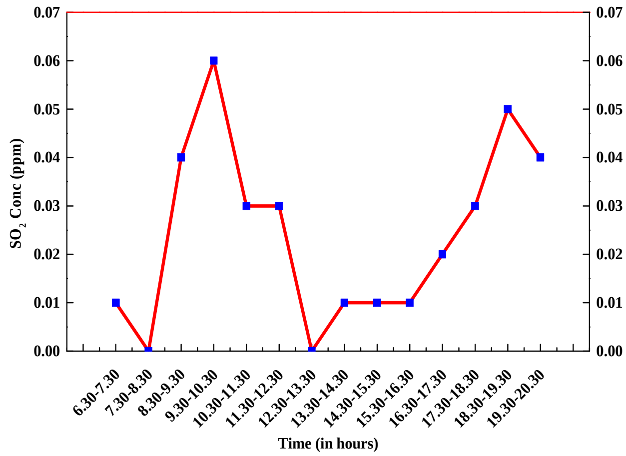

Fig. 5.3: Variation in concentration of SO_2 using LPG fuel

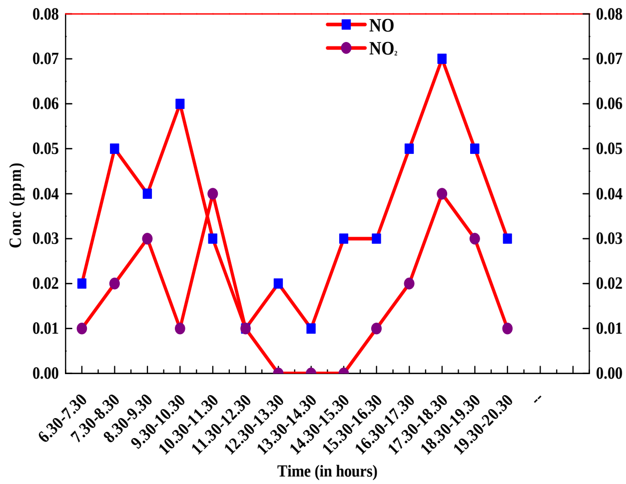

Fig. 5.4: Variation in concentration of NO & NO_2 using LPG fuel

4. LINKAGES OF RESPIRATORY DISEASE SYMPTOMS WITH FUEL USE AND KITCHEN LOCATIONS

The linkages between self-reported respiratory disease symptoms includes cough, phlegm, breathlessness, wheezing, blood in sputum and any other symptoms like fever, sore throat, running nose etc. On the basis of self-reported symptoms the occurrence of respiratory diseases were examined in the households using different type of fuels (biomass. LPG) and cooking in different locations is in Table 2.

Table 2: Linkages of respiratory disease symptoms and fuel use, and kitchen location (in percentages) in the sampled households.

Biomass fuel and LPG								
Type of fuel used	**No. of households**	**Cough**	**Phlegm**	**Breathlessness**	**Wheezing**	**Blood in sputum**	**Eye irritation**	**Any respiratory symptoms**
Biomass	**50.00**	**14.59**	**9.45**	**11.60**	**12.25**	**5.52**	**5.04**	**18.15**
LPG	**50.00**	**4.23**	**3.32**	**4.00**	**4.34**	**1.67**	**3.88**	**9.69**
Kitchen location								
Verandah	**50.00**	**2.88**	**2.31**	**3.07**	**3.46**	**0.77**	**5.77**	**5.21**

5. CONCLUSIONS

The results suggest that the average concentration of indoor air pollutants was highest during cooking hours with biofuels. The study reveals that the concentration of indoor pollutants, especially particulate matter, carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxide, nitrogen dioxide is maximum when cooking is done using biomass in chulhas. The exposure to chief cook is very high in all types of kitchens (whether cooking in the verandah or in open air) when cooking is done using biomass. Another important finding is that the household members who are inside the house during the cooking hours also face the effects of high exposures. This is because most of the households using biomass burn them in open fires/ chulhas that release most of the smoke into the house. The resulting indoor air pollution is a major threat to health, particularly for women and young children who may spend many hours close to the fire. Much higher levels of pollutants are released during cooking hours. According to environmental protection agencies (EPA), the particulate of 10 µm or less than that in size easily passes through the nose, throat and enter the lungs posing health risks. The increase in mortality rate on a global scale from 4 per cent to 8 per cent of premature deaths is due to exposure to high levels particulate matter in the ambient and indoor environment [7].

6. ACKNOWLEDGEMENTS

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