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Study of Indoor Air Quality of Kitchens of Rural Area's in Lucknow

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ABSTRACT

Study deals with the assessment of Indoor Air Quality (IAQ) in terms of Particulate matter, Gaseous pollutants, Polycyclic Aromatic Hydrocarbons (PAH) during domestic combustions of biofuels (i.e. Fire wood, animal dung and Crop residues) in the cooking and non-cooking area of rural kitchens of the rural suburbs of Lucknow (North India). The indoor air samples of kitchens when analyzed for various pollutants, revealed very high concentrations of CO, CO_2, NO_2 and SO_2 in cooking area (kitchen area) as compared to non-cooking area (living area). Burning of biofuels (Fire wood, animal dung and Crop residues) produced highest emission of PAH. Increment in PAH level was found in the cooking area (kitchen area) as compared to PAH level in the non-cooking area. The concentration of PM_{10} in the indoor air sample was 3.7 times more than that found in the living area. Similarly, the concentration of $PM_{2.5}$ was four times higher in kitchens using biomass during cooking hours.

Key words: Indoor air quality, Domestic cooking, Rural women, Biomass fuel.

INTRODUCTION

In developing countries the problem of indoor air pollution is increasing at an alarming rate. In rural areas of India, the most important indoor air pollutants are combustion products of unprocessed solid biomass fuels used by the poor rural folk for domestic cooking (ICMR Bulletin, 2001). Approximately half of the world's population and up to 90% of rural households in developing countries still rely on unprocessed biomass fuels such as wood, dung and crop residues (Bruce et al., 2000). A recent report of the world Health Organization (WHO, 2005) asserts the rule of 1000 which states that a pollutant released indoors is one thousand times more likely to reach peoples lung than a pollutant released outdoors. It has been estimated that about half a million women and children die each year from indoor air pollution in India (Smith, 2000). Biomass fuels viz. animal dung, crop residues and wood, which are the most hazardous fuels, are used mostly by very poor rural women for cooking. It has been estimated that these fuels on combustion release at least 50 times more noxious pollutants than LPG (Smith, 2003).

The biofuels are not burnt completely and release complex mixtures of organic compounds which include suspended particulate matter (SPM), Carbon Monoxide (CO), Poly Organic Material (POM), Polycyclic Aromatic Hydrocarbons (PAH), and intrinsic contaminants such as sulphur, and trace metals etc. Incomplete combustion of biofuels produces CO. use of biofuels poses serious disease burden among Indians as compared to other countries (Smith, 2000). While during the use of liquid petroleum gas (LPG) a negligible amount of CO is released. A study by the National Institute of Occupational Health (NIOH, 1995) reported indoor air CO levels of 144, 156, 94, 108 and 14 mg/m^3 during cooking by dung, wood, coal, kerosene and LPG respectively. The gaseous by products such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), Ozone (O_3) have been the most implicated pollutants found in indoor air due to combustion of biofuels (Devalia et al., 1997; Davlis et al., 2003 and Rios et al., 2004).

Aim of the study was to report the findings of indoor air quality (IAQ) of the rural households using different biofuels viz. firewood, animal dung and crop residues in terms of particulate matter as the primary pollutant, gaseous and other particulate products at two sites i.e. Cooking area (kitchen area) and Non-Cooking area (living area) as most of the rural domestic cooking is done in these areas.

Methodology

The indoor air samples from cooking area (kitchen area) and non-cooking area (living area) were collected during cooking and non-cooking times from nearly 30 households situated in rural suburbs of Lucknow (North India). The households in the study group used earthen chullahs. Personal samplers were installed in these areas for monitoring purposes. For respirable dust measurements the samples were collected by drawing air through battery operated constant flow pumps.

The concentration of PM_{10} in cooking area and non-cooking area were measured by portable, real time aerosol monitor (Dust Track TM, model 8520, TSI Inc, MN, USA). The apparatus contains 10 mm nylon Dor-Oliver cyclone, operates at a flow rate of 1.7 liters/minute and measures particles load in the concentration range of 10ìg-100 mg/m^3. Since the biomass using women, cook in a sitting posture at 2-3 feet away from the open chullah, the monitor was placed in the breathing zone of the women cooking at 2.5 feet above the floor level on a wooden stool, 3 feet away from the chullah. Measurements of CO, CO_2, $PM_{2.5}$, SO_2, NO_2 and PAH were monitored and analyzed using HPLC/FLD (High Performance Liquid Chromatography/Fluorescent Lumen Devices) and UV (Ultraviolet) during cooking and non-cooking area of indoor air. These PAH or polynuclic aromatics (PNA) are the principal pollutants from incomplete combustion which are of special interest due to their toxicity.

RESULTS

Burning of biofuels resulted indoor smoke leading to particulate pollution. The indoor air during cooking hours showed significantly higher concentration of gaseous pollutants i.e. CO, CO_2, SO_2 and NO_2 in the indoor air (kitchen area) during cooking hours with the highest values at breathing level is depicted in Table-1, Fig-1. High concentration of CO_2 and CO release was observed in cooking area compared to NO_2 and SO_2 release during cooking hours. Data clearly depicts that biofuels burning released more of NO_2 compared to SO_2 (Fig-1). Burning of wood fuel produced the highest emission of PAH due to intensive use of biofuels for domestic combustion. The PAH level was found to be in the range 395-1157 µg/m^3, compared to 62.3-127.5 µg/m^3 in outdoor air (Table-2, Fig-2).

The concentration of PM_{10}, $PM_{2.5}$ in cooking as well as non-cooking area during cooking hours is depicted in Fig-3 and 4 respectively. Concentration of PM_{10} was significantly 3.7 times more in kitchen area as compared to non-cooking area during cooking hours (P<0.001). Even during the non cooking hours, PM_{10} level in cooking area was significantly more than double when compared to non-cooking area i.e. living area (736 vs. 198 ìg/m^3, P<0.001) respectively. Similarly, the concentration of $PM_{2.5}$ (Fig-4) in biomass using kitchen was three times significantly higher in cooking (367 vs. 121 ìg/m^3, P<0.001) and two times higher in non-cooking area during cooking and non-cooking hours respectively (177 vs. 81 ìg/m^3, P<0.001).

The concentration of PM_{10} and $PM_{2.5}$ during 24 hour monitoring in kitchen and living areas of rural households were found significantly different during cooking and non-cooking hours (Fig-5), including maximum concentration of smoke particles in the environment of indoor kitchens as compared to separate living area.

DISCUSSION

Kitchen measurements of CO, CO_2, NO_2 and SO_2 and the respiratory particulate matter (RSPM, 2.5ì and the ultrafine particles (UFP) (size range 0.007 to 0.1 ìm) in the indoor environment emitted by the combination of biofuels during domestic cooking used by the rural women folk studied in this survey are comparable to a number of other similar studies (Naeher et al., 2000; Smith et al., 2003; Ellegard, 2007; Dockery and Pope, 2009).

Although it is difficult to fully compare the current study to the others because each deals with different cooking fuels, different sample durations, techniques and different size of the particulate pollution. The levels of classical air pollutants such as CO, CO_2, NO_2, and SO_2 were found to be significantly higher both in the breathing zone i.e. cooking area near the chullah and also in the indoor ambient air i.e. non-cooking area during cooking using biofuels in comparison to TLVs (Threshold Limit Value) laid down by National Ambient Air Quality Standard (NAAQS, 2000), American Council Of Government Industrial Hygienists (ACGIH, 1983) and United Nation Environmental Protection (UNEP, 1997). The high concentration of these gases is considered to be the major source of respiratory and cardiac mortality among the exposed rural women, their families including new born infants. The epidemiological studies (Mac Nee et al., 2002; Mann et al., 2004; Kreuter, 2004) have shown that the inhalation of the combustible products from biomass fuels can exacerbate the outgoing disease processes in the exposed rural women. Alarming rate of increase in PM_{10} and $PM_{2.5}$ has been observed by several researchers which is detrimental for health of living beings. Today, the focus is on $PM_{2.5}$ emission resulting from combustion and its implications for air quality and human health are linked to the major etiological factor for indoor air pollution (WHO, 2000; Akinson et al., 2001).

Significantly high emission of the PAH in the Indian rural kitchens observed could be due to several factors during combustion of biofuels. The PAH are the principal pollutants , which are of special interest due to their toxicity, carcinogenicity and imposing ubiquitous pressure to the environment is primarily produced due to incomplete combustion of biofuels during domestic cooking. The other studies on PAH emission from combustion of biofuels indicated its intensive use, leading to high emission factors of PAH which is probably related to the high volatile content of biofuels, which commonly correlates to higher possibility of incomplete burning

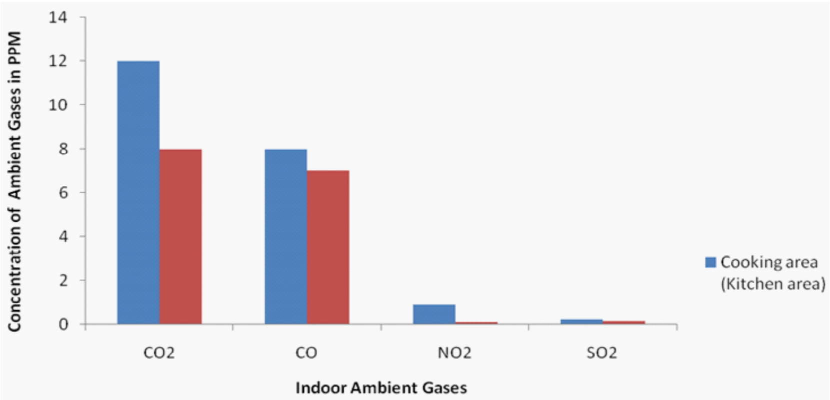

Fig.1: Gaseous pollutants in the indoor ambient air of kitchen area and living area

Table. 1: Concentration of air- borne gases (ppm) released during cooking using biofuels in rural area

Pollutants (ppm)	Cooking area (kitchen area)		Non-cooking area (living area)	
	Mean	Range	Mean	Range
CO_2	12.00 ± 3.40	9.00 - 44.50	8.09 ± 2.65	6.80 - 30.40
CO	8.40 ± 3.30	6.80 - 31.20	4.40 ± 2.10	4.00 - 18.60
NO_2	0.90 ± 0.11	0.60 - 0.99	0.10 ± 0.01	0.05 - 0.21
SO_2	0.25 ± 0.10	0.21 - 0.40	0.15 ± 0.04	0.12 - 0.21

Values are means of replicates ± SD.

(Oanh et al., 2005). Poor kitchen ventilation is an important factor for high concentration of PAH in rural Indian kitchens. We found very poor kitchen ventilation in most of the rural houses surveyed by us during the study. There were no chimneys or exhausts in any of the rural kitchens. This in together with low efficiency cook stoves or chullahs and large amounts of biofuels usage resulted in serious indoor air pollution thus leading to high levels of PAH (World Health Organization (WHO, 1999); United States Environmental Protection Agency (USEPA, 1997).

Table. 2: Concentration of PAH (μg/m³) in cooking and non-cooking area

	PAH concentration (μg/m³)	
	Inside the kitchen (cooking area)	Living area (non-cooking area)
Mean	957.0±100.4	157.6±24.6
Range	395.0-1157.0	62.3- 127.5

Values are means of replicates ± SD.

High values of PAH, CO, NO_2, PM were accounted at sitting breathing zone when biomass (dung cake, fuel wood and other agricultural residues) were used. This accounts for more than 90% of the total fuel consumption in rural areas, during domestic cooking. Several studies have reported that in rural houses of developing countries the PAH level was found to be in the range 100-10,000 ng/m³ (Khandpal et al., 1995; Gupta et al., 1998). The magnitude of air pollution from biomass smoke can be judged from the report that concentration of RSPM in Indian kitchens is thirty times of the WHO guideline while its outdoor concentration is two and half times of the

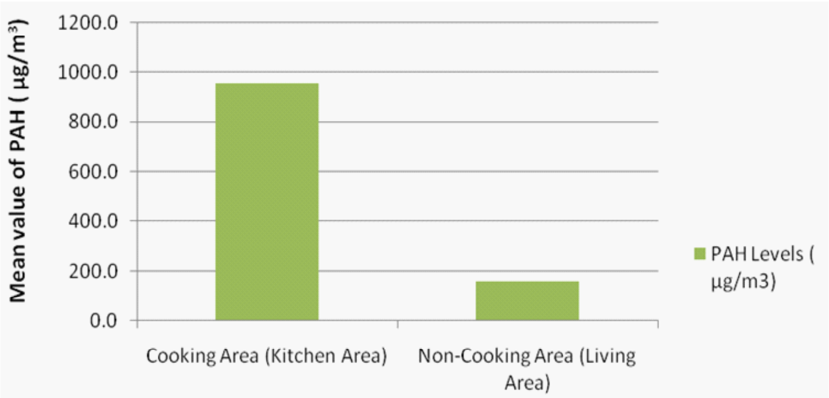

Fig.2: Mean value of PAH in Cooking Area (Kitchen Area) and Non-Cooking Area (Living Area) using biofuels in the rural kitchens.

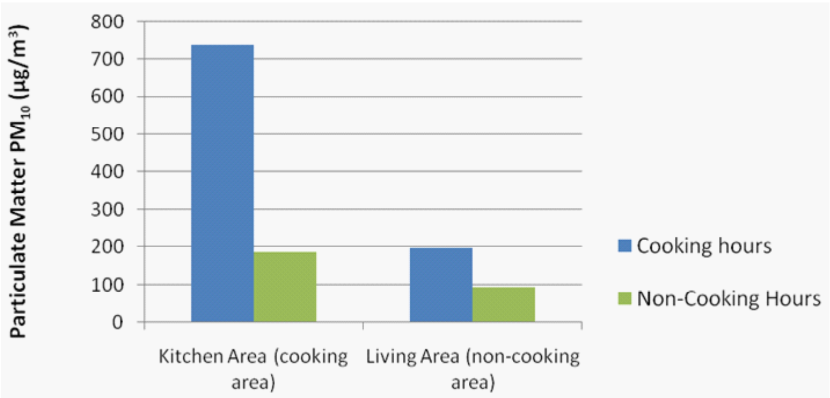

Fig.3: Particulate Matter (PM_{10}) in Cooking hours (Kitchen area) and Non-Cooking (Living area) in Rural kitchens using biomass.

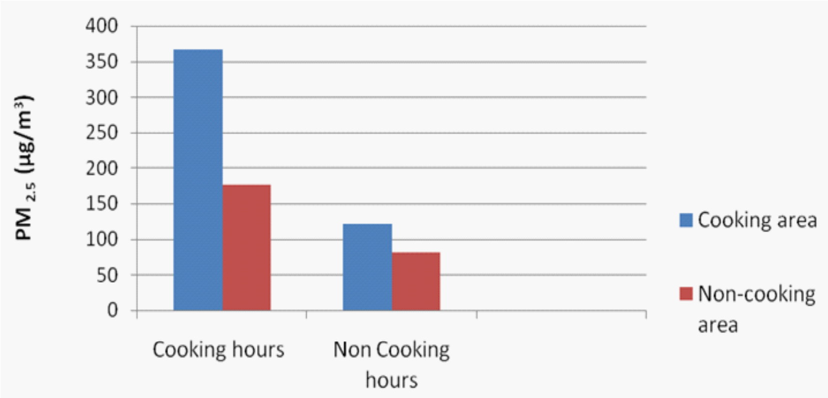

Fig.4: Particulate Matter ($PM_{2.5}$) in rural kitchens during cooking and non-cooking hours using biomass as fuel.

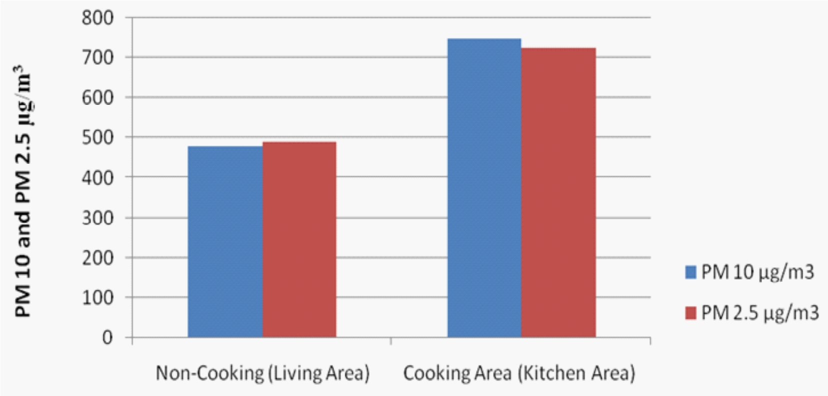

Fig.5: Concentration of $PM_{2.5}$ and PM_{10} during 24 hour monitoring in non-cooking (living area) and cooking area (kitchen area).

guideline of Tata Energy Research Institute (TERI, 1997; WHO, 1999). Engle et al., (1997) observed that the people of the developing countries are typically exposed to very high levels of indoor air pollution for 3 to 4 hours a day. Since it is always the women who cook daily household meals, their exposure is much higher than men's (Behera et al., 2001).

It can be concluded on the basis of survey study that there is significant health risk associated with increased concentration of gaseous pollutants and suspended particulates including PAH. Our study, therefore, recommends more stringent bio monitoring studies and use of high efficiency cooking devices to cut down the emission of toxic chemicals, gases etc during combustion of biofuels in Indian rural kitchens along with better kitchen ventilation.

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