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# Predicting Exposure Levels of Respirable Particulate Matter (PM2.5) and Carbon monoxide for the Cook from Combustion of Cooking Fuels

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**Abstract.** The use of biomass fuels for cooking is the largest source of indoor air pollution in India, particularly in rural areas. The emissions of particulate matter less than 2.5 micron (PM2.5) and carbon monoxide (CO) were monitored during cooking and non-cooking periods in rural households of Jhajhar district of Haryana. The fuel/stove combinations monitored for emissions include various stoves types (Chulah, Hara and LPG) and fuel types (dung cake, crop residues, wood, and LPG) thus representing a large fraction of the total fuel/stove combinations used in study area. The CO concentration during cooking varied from 3.36 ppm for LPG to 157 ppm for crop residue/Chulah. Similarly PM2.5 concentration during cooking varied from 4.69 $\mu g/m^3$ for gas/LPG stove to 11000 $\mu g/m^3$ for dung cake/Chulah. Combining the results of time activity pattern of cook and PM2.5 and CO concentrations during cooking and non-cooking periods, exposure estimates for cook were calculated. Average 24-hour exposure for CO for Gas/LPG stove was 0.44 ppm, for wood/Chulah was 17.2492 ppm, for crop residue/Chulah was 19.34 ppm, for dung cakes/Chulah was 33.50 ppm and for mix fuel was 17.7167 ppm. The value of average 24 hour PM2.5 for gas/LPG stove was 25.67 $\mu g/m^3$, for wood/Chulah was 222.69 $\mu g/m,^3$ for crop residue/Chulah was 393.39 $\mu g/m,^3$ for dung cake/Chulah was 774.5190 $\mu g/m,^3$ and for mix fuel/Chulah 376.40 $\mu g/m.^3$ The database can be used to have an estimate of CO and PM2.5 emissions for areas with similar fuel use patterns. In households with limited ventilation as is common in rural household, exposures experienced by household members, particularly women who spend a large proportion of their time in kitchen, have been measured to be many times higher than WHO guidelines and national standards.

**Keywords:** cooking; exposure; PM2.5; Carbon monoxide; fuel.

## 1 Introduction

Cooking is central to our lives. Nearly half the world cook with solid fuels such as dung cakes, wood, agricultural residues and coal. More than 2 billion people of the world, mostly in poor, developing countries of Asia, Africa and Latin America, rely on biomass fuels as the primary source of domestic energy [1]. Majority of India's people still reside in rural areas [2] and use a variety of fuels like wood dung, crop residue, coal, kerosene, LPG and biogas to meet household energy demands. The choice of fuel mainly depends on the income of household and availability of fuel. Besides economic reason, there are some socio-cultural practices that influence people's fuel choice [3]. Therefore solid biomass fuels are used even in areas with access to modern fuels. According to the 61st round of the National Sample Survey of India, 84% of rural households rely on biomass as their primary cooking fuel [4]. The traditional stove called 'chulah' is most commonly used for cooking in India. When used in simple cooking stoves, the biomass fuels emit substantial amounts of toxic pollutants. The measurement of concentrations of small airborne particles and CO is vital to understand adverse health effects from cooking smoke as well as monitoring trends and the degree of improvement due to control options. Health effects are not solely dependant on concentrations; rather they are dependent on the doses received by individuals. So exposure is much better proxy for health effects, than is ambient concentration alone. In developing countries the use of solid biomass fuels for cooking and heating, often results in high human exposure to pollutants, and apparently contribute significantly to premature mortality and illness. The present paper reports the findings of a study done to know the exposure levels of PM2.5 and CO to which the cook is exposed to while cooking with different fuels and stoves.

# 2 METHODOLOGY

***Study area:*** The rural sites selected for the present study were five village of district Jhajjar of Haryana state, India with geographical coordinates 28'40 north and 76'52 east, which is situated nearly 40 km in northwest direction from logy, New Delhi, the capital city of India..

***Monitoring of PM2.5 and CO:*** The concentrations of PM2.5 and CO in cooking areas during cooking as well as non-cooking hours were measured in 125 households of five villages @ 25 households in each village by using portable, real-time aerosol monitor (*UCB particle monitor*, Berkeley air group, California, USA) and *Testo 350 XL* (Testo Ltd., Germany) respectively. The UCB can measure PM 2.5 per minute and stores it in its memory. Since biomass-using women usually perform cooking in a sitting position on the floor, therefore the monitors were placed in the breathing zone of the cook 2.5 feet above the floor level on a stool and 3 feet away from the chulah. LPG users, on the other hand, generally cook in a standing position, and the monitors were placed accordingly at a height of 4 feet and 3 feet away from the oven.

***Time activity Survey:*** 24- hour recall was used to assess the time spent by each household member in the cooking and non-cooking windows and the same was used in calculation of exposure levels of the cooks in each household.

***Exposure estimate for the cooks:*** Combining the results of time activity pattern and PM2.5 and CO concentrations in cooking and non-cooking periods (Kitchen, living area and outdoor), a model was developed to predict exposure estimates for cook of each household using following set of measurements:

1. Average concentrations in the households during cooking, average concentrations in the households during non-cooking and average concentrations in the outdoor environment.
2. Total time spent by each cook at these locations during the preceding 24-hrs (obtained from time activity records).

**Average 24-hr exposure** = $\frac{K1*T1+L1*T2+O1*T3}{T1+T2+T3}$ **(1)**

Where K1= 24-hr average concentration in kitchen

T1= Total time spent in kitchen

L1= 24-hr average concentration in living area

T2= Total time spent in living area

O1=24-hr average concentration outdoors

T3= Total time spent outdoors

T1+T2+T3= 24

# 3 RESULTS

The concentrations of PM2.5 and CO during cooking were very low for LPG/gas followed by Acacia wood, Neem wood, Pigeon pea stalks, Mustard stalks (crop residue) and dung cakes in the increasing order (Figure 1). The average 24 hour PM 2.5 ranged from 22-28 $\mu g/m^3$ and 708-840 $\mu g/m^3$ for gas/LPG stove and dung cake/Chulah using households, respectively. One-way ANOVA analysis of cooking area concentrations across fuel categories shows that the levels were significantly different across fuel types. Time spent by cook near fire varies from house to house and it ranged from 1-6 hour/day depending on the number of family members for whom food is cooked.

The analysis of exposures levels for cooks across households using various fuels show that exposures were significantly different across fuel categories (fig.2). This parallels the trends in both PM2.5 as well as CO concentrations that were also significantly different across fuel types. Dung produced the highest concentrations and exposures followed by crop residue, wood, kerosene and gas in that order. This suggests that average household exposures are reflected well by average concentrations.

# 4 DISSUSION

Most of the study households were burning biomass fuels in traditional earthen or three stone stoves without chimneys which causes significant levels of indoor air pollution in the cooking area.

Kandpal et al. [5] tested four types of biomass fuels: animal dung cake, crop residue (mustard stalk), fuel wood (Acacia), and a mixture of fuel wood and dung cake in a traditional U-shaped cookstoves and an improved mud cookstoves. Regardless of which stove was used, the CO concentrations measured in the kitchen air was the highest during burning of dung cake, followed by the dung-wood mixture, crop residue, and fuel wood. So we can say that the trends found in our study across the tested biomass fuels are consistent with that shown in earlier studies and also agrees with the energy ladder concept. Smith et al. [6] found the measured levels of health damaging pollutants from biomass stoves more than 10 times higher than those specified in the relevant standards.

The CO standards for residential area are 2 $mg/m^3$ of 8-h average (16 $hmg/m^3$ exposure equivalent) in India. These national standards could be easily exceeded by CO exposures caused by traditional biomass stoves. In households with limited ventilation, exposures experienced by household members, particularly women and young children have been measured to be many times higher than World Health Organization (WHO) guidelines and national standards set by CPCB [7,8,9]. Emissions contain many other toxic and potentially toxic compounds as well, such as, carcinogenic VOCs (e.g., benzene, 1,3-butadiene), sulfur dioxide, nitrogen dioxide, aldehydes, polycyclic aromatic hydrocarbons, and particulate matter [10,11]. These pollutants sum up together to produce health risks for people who are repeatedly exposed to the emissions.

# 5 CONCLUSION

The findings of this study strengthen the evidence that the use of biomass fuels/traditional stoves for household energy exposes the cook to levels of air pollution that well exceeded health guidelines available for outdoor air quality, this holds true even when cooking is done outside the house in the open air or in a separate kitchen. Women, in their traditional capacity as cooks, had much greater exposures than other family members emphasizing an important gender dimension of the IAP problem.

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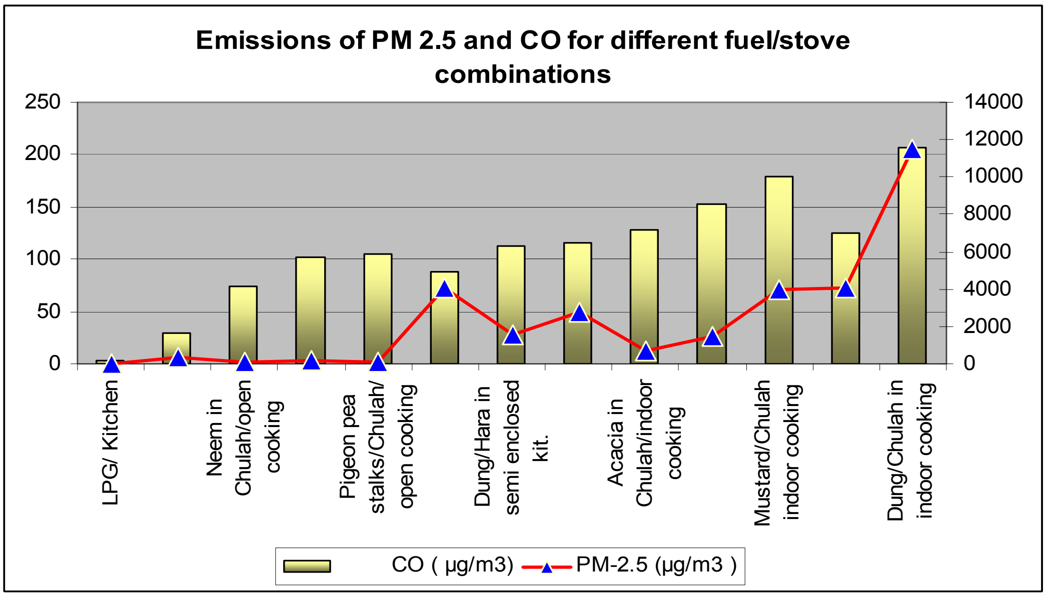


Figure 1. PM2.5 and CO concentrations during Cooking with different fuel/stove combinations

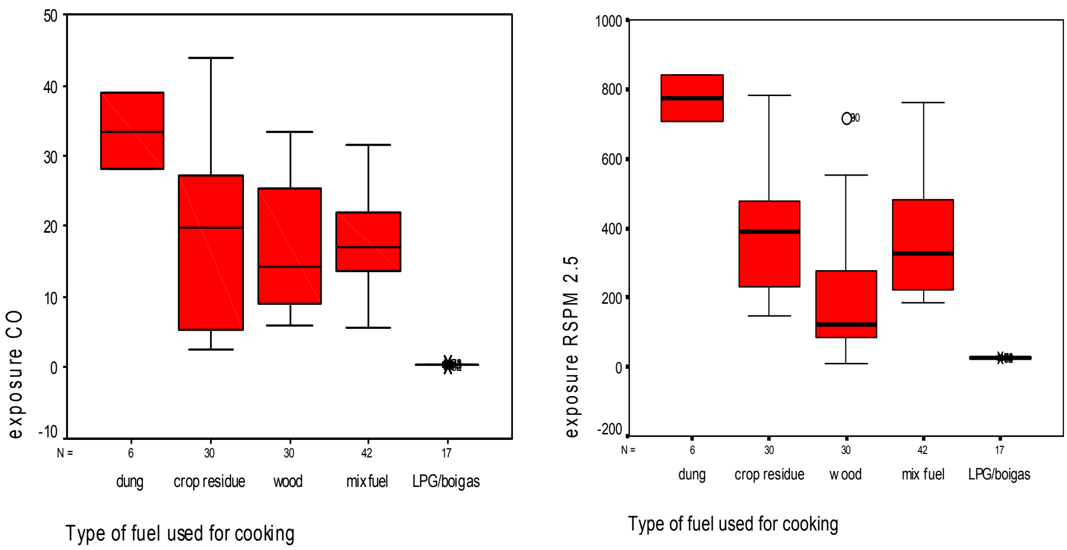


Figure 2. Exposure levels for the cooks to CO and PM2.5 for different fuels