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$PM_{2.5}$ ARISING FROM DIFFERENT COOKING FUELS IN RURAL RESIDENTIAL HOUSES

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ABSTRACT

A study was conducted in the rural area of Kasur district, Pakistan to monitor $PM_{2.5}$ levels generated by different fuel types. Three rural houses were selected, one burning wood as primary cooking fuel while the other two employed LPG for cooking purposes. Burning of wood caused PM levels to increase 37 times above the WHO recommended limit of 25 µg/m³ while smoking also contributed significantly increasing PM levels up to 48 times than the recommended limit. LPG was observed to increase the levels up to 14 times. It is important to promote the use of cleaner fuels as increased exposure to PM levels generated by biomass fuel burning can have a significant impact upon human health.

Keywords: Particulate matter,Biomass fuels, LPG, Rural houses, Pakistan

INTRODUCTION

Globally, 2.7 billion people employ solid biomass fuels for cooking purposes (IEA, UNDP and UNIDO, 2010) and 4.3 million deaths were attributable to household air pollution in 2012, almost all in low and middle income countries. The smoke resulting from these fuels is responsible for causing deaths due by stroke, ischaemic heart disease, chronic obstructive pulmonary disease and acute lower respiratory infections (WHO, 2009).

Use of biomass fuels as an energy source is major case of indoor air pollution in Pakistan (Colbeck*et al*, 2008). Almost 86% of the rural population burns biomass fuels including wood, cow dung and crop residues. Among these, wood has the highest usage of about 54 % (Archar, 1993). Although Liquefied Petroleum Gas (LPG) and Natural Gas (NG) are cleaner fuels, PM generation from these fuels in the rural areas has not been studied yet. Surroundings are an important factor in describing indoor air quality (IAQ) as the outdoor load of pollutants can easily enter the indoor micro-environments. Moreover, in developing countries, natural ventilation is the more common mode of ventilation which allows infiltration of pollutants into the indoor environments.

Many studies have documented PM levels generated form biomass fuel burning and subsequent health impacts (Siddiqui *et al*., 2005a, 2005b, 2009; Akhtar *et al*., 2007; Colbeck *et al*, 2008, 2009; Nasir *et al*, 2013). However, the levels of PM emissions from cleaner fuels in rural areas have been ignored to great extent. We need to have knowledge on comparative levels from rural households using cleaner fuels. The current study was conducted as a case study to demonstrate the impact of different household fuel usage on exposure to fine particulate matter in rural households.

MATERIALS AND METHODS

Study area: Allah Abad is a small village in Kasur district of Punjab province, Pakistan (N 30 53' E 074 03'). Three residential houses from the village were selected for monitoring of indoor air quality. The selection was made on the basis of fuel used for cooking and also the floor area of the houses (including the built area and courtyard/s as well). Table 1 is a brief description of the selected sampling sites including the type of cooking fuel.

Table 1. Description of the study sites

Sampling site	Floor area (m^2)	No. of occupants	Type of cooking fuel	No of smokers	Connection b/w kitchen and living room
1(3)	88.55 m²	6	LPG	0	Partially connected
2(1)	189.75 m²	9	LPG	0	Partially connected
3(2)	253 m²	12	Wood	4	Not connected

Experimental setup: Two indoor micro-environments were selected at each house i.e. kitchen and living room as these rooms are in use for most part of the day and so exhibited maximum activities of the occupants. Monitoring of fine particulate matter was carried out with a real time aerosol monitor, Dust Trak (Model 8520, TSI Inc.). The monitors were factory calibrated before sampling was conducted and the air flow was maintained at 1.7 l/min. Two monitors were run in parallel, one in each micro-environment for forty eight hours. The instruments were placed at a height of 1 meter above the ground and at some distance away from the stove in kitchens. The activities of the occupants were recorded to observe their possible impact upon PM levels.

The ventilation rates at each site were measured using the tracer gas decay method (Fischer-Mackey, 2010). The process was carried out with open doors and windows to measure maximum air exchange rate and then repeated with closed doors and windows for minimum air exchange rate.

RESULTS AND DISCUSSION

Levels of fine particulate matter in the indoor environments can be attributed to the wide variety of indoor activities. Moreover, these levels also vary according to location as higher PM levels have been recorded in rural residential settings as compared to urbanized areas. Our study encompassed PM generation from two different fuel types in rural residencies. The 24 hour average $PM_{2.5}$ levels in the kitchens were 252 ±75 µg/m³ at site 1, 465 ±184 µg/m³ at site 2, and 970 ±738 µg/m³ at site 3. Similarly, in the living rooms of all three sites the respective mean $PM_{2.5}$ levels were 416 ±163 µg/m³, 442 ±128 µg/m³ and 1193 ± 885 µg/m³ (Table 2). Wood burning and smoking was identified to be the source of the elevated values at site 3. The other two sites employed LPG as cooking fuel while no one smoked in these two households. The highest mass concentration at site 3 is a fine illustration of the amplified particulate matter pollution due to burning of biomass fuels. The hourly $PM_{2.5}$ mass concentration by wood burning varied from 537 to 3524 µg/m^3 during a 48 hour cycle and our results show accordance to a study conducted in Costa Rica by Park and Lee (2003). According to this study the $PM_{2.5}$ maximum particulate production was found during cooking by burning wood.

Table 2. Concentrations of fine particulate matter at the selected sites

	Site 1		**Site 2**		**Site 3**	
	$PM_{2.5}$ in kitchen (µg/m³)	**$PM_{2.5}$ in living room (µg/m³)**	**$PM_{2.5}$ in kitchen (µg/m³)**	**$PM_{2.5}$ in living room (µg/m³)**	**$PM_{2.5}$ in kitchen (µg/m³)**	**$PM_{2.5}$ in living room (µg/m³)**
AVE	252	416	465	442	970	1193
SD	75	163	184	128	738	885
MAX	426	815	930	765	2858	3524
MIN	151	204	214	212	347	537

AVE (Average), MAX (Maximum), MIN (Minimum), SD (Standard Deviation).

Varying levels of fine particulate matter were observed in all three houses. Major activities were identified to be cooking and cleaning in the kitchens while in the living rooms, cleaning, movement of people and smoking contributed significantly (Figures 1 and 2).

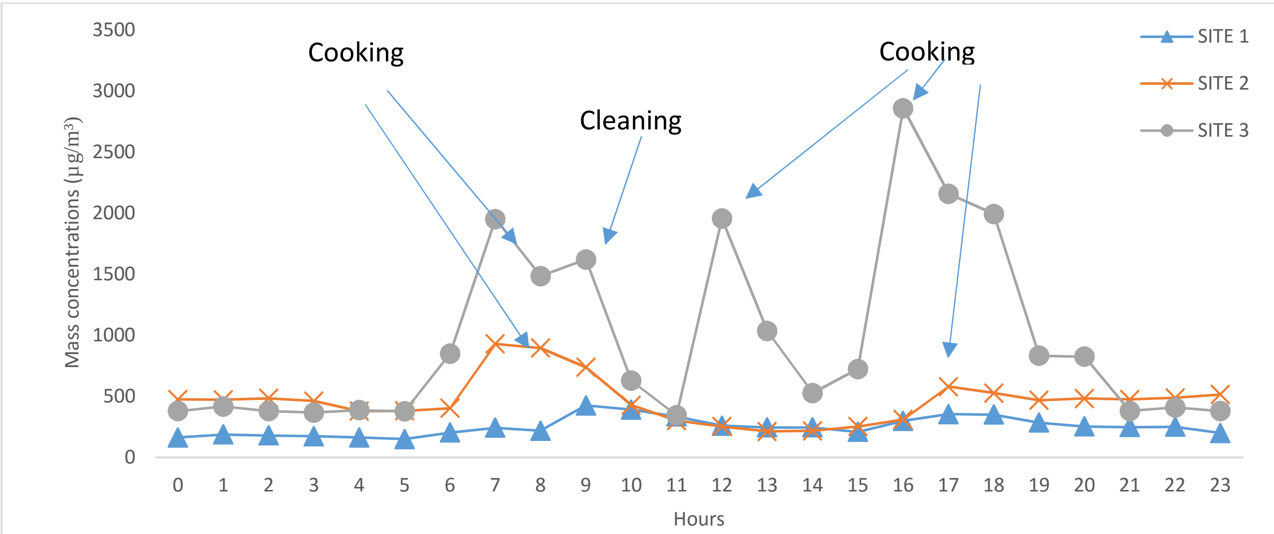

Figure 1: Hourly trend of $PM_{2.5}$ in the kitchens of sampling sites

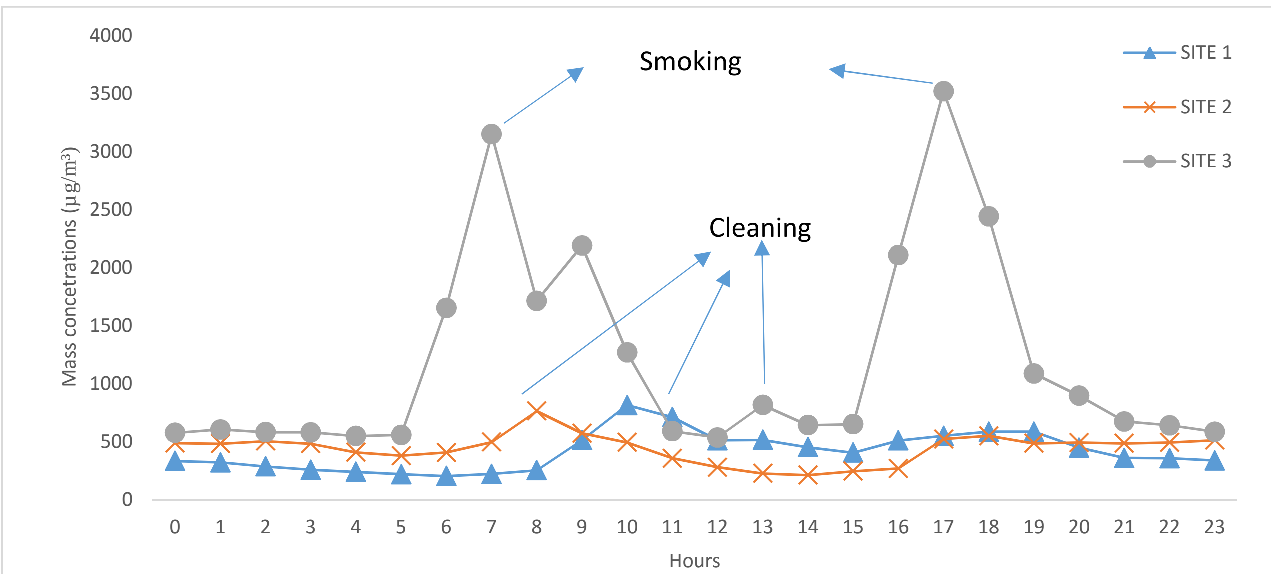

Figure 2. Hourly trend of $PM_{2.5}$ in the living rooms of sampling sites

Ventilation practices are also an important aspect in defining the IAQ as air exchange with the external environment dilutes the indoor air and helps in reducing pollutant loads. For a healthy indoor environment, the minimum air exchange rate per hour should be at least 4 ACH. In our sampling sites, the ventilation rates, especially in the living rooms, were poor (Table 3).

Table 3. Air exchange rate in the selected sampling sites

Sampling site	KITCHEN		LIVING ROOM	
	Maximum ACH	Minimum ACH	Maximum ACH	Minimum ACH
SITE 1	7.4	4.3	5.7	2.6
SITE 2	5.5	3.7	2.4	1.1
SITE 3	4.0	3.8	5.2	1.2

Poverty creates a hindrance in selection of cleaner fuels and is an important factor in choice of fuel in the developing countries. Although biomass fuel results in higher pollutant levels, people rely on solid fuels as it is cheaper and readily available (Nasir *et al*., 2015). In our study it was noted that LPG was more costly than wood and so was less preferable in households with low incomes. The lack of awareness about adverse health effects caused by biomass fuel was also found to be one of the reasons to choose it.

Conclusion: Use of cleaner fuels leads to less emissions as compared to burning of biomass fuel. However, financial resources are a major aspect in choosing the type of fuel in rural households. It was observed that burning of wood as cooking fuel lead to about 39 times more PM generation than recommended by the WHO. Smoking was another major contributor which was responsible for even higher levels of $PM_{2.5}$ i.e. 48 times higher than the WHO limits. On the other hand, LPG users were less exposed to PM levels indoors.

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