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Indoor air pollution of $PM_{2.5}$ in urban households of Jammu (J&K)

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Abstract
The rising problem of Respirable Particulate Matter i.e. $PM_{2.5}$ and smaller is catching attention of the policymakers, stakeholders as well as common man. The study of the Indoor$PM_{2.5}$ of the particular area is very important as it is having direct impact on the human health because $PM_{2.5}$ is absorbed into lung alveolar tissues during breathing and causes respiratory and cardiovascular problems. In present study attempt has been made to assess the status of Indoor $PM_{2.5}$ in Urban Households of Jammu, (J&K). The average indoor $PM_{2.5}$ in all the sampled households of Jammu was observed to be 99.49±35.84 µg/m^3 which is above the permissible limits of PM 2.5 as prescribed by CPCB. This type of study has been done for the first time in the northern region of India. The data generated in present study will act as base line data for further studies pertaining to its ionic analysis as well as suggesting mitigation measures.

Keywords: Cooking fuel, Households, Indoor air, $PM_{2.5}$

INTRODUCTION

Both the directly emitted particulate matter (primary) as well as chemically produced particulate matter (secondary) are important atmospheric pollutants released into the atmosphere. The quality of the air inside buildings comprising the pollutants, temperature and relative humidity conditions which affect the health and performance of residents is called Indoor Air Quality (IAQ). Keeping in view principle of human rights to breathe healthy indoor air to keep good health (IAQ) has become one of the most important issues of environment and health worldwide (CPCB, 2014).
Urban and sub-urban air contains significant concentrations of aerosol particles which are get released from both natural as well as anthropogenic activities. The size of aerosol varies from few tens of angstroms to several hundred micrometers (Seinfeld and Pandis .(012 2 ,$PM_{2.5}$ and smaller particles were have direct impact on the human health because $PM_{2.5}$is absorbed into lung alveolar tissues during breathing and causes respiratory and cardiovascular problems. The release of fine particles like $PM_{2.5}$released take place due to condensing of the elements from the gas phase to the form of nuclei, at a low equilibrium of the vapour(Al-Jumaily,2016)
There is a great need to address one of the major environmental problem i.e. pollution due to cooking fume (Lin *et al*, 2014). Status assessment of particulate matter (PM) of the particular place and subsequent exposure of inhabitants to particulate matter (PM) is prerequisite to suggest the development of control strategies for ambient PM. Lot of work has been done on the status and assessment of outdoor air pollutants but very little work has been done regarding Indoor air pollutants particularly $PM_{2.5}$ at national level and no work has been done in Jammu In present study attempt has been made to assess the status of indoor $PM_{2.5}$ in Urban Households located at residential areas, commercial areas and industrial areas of Jammu, (J&K) during the summer season.

MATERIALS AND METHODS

The study area Jammu, the winter capital of J&K, is surrounded by the Himalayas, lying on the banks of the river Tawi with an area of 26.64km² is located at 32.73°N 74.87°E at an average elevation of 300 m (980 ft). The study was conducted during summer season (March-June), 2018. The area was divided into residential (Sidjra, Channi Himmat, Sainik Colony Muthi, Bantalab, part of Gandhi Nagar, Trikuta Nagar, Nanak Nagar) commercial (part of Gandhi Nagar, Jewel,Janipur, New Plot, Bakshi Nagar, Paloura, TalabTillo) and industrial sites (Gangyal) (Fig.1). At each site three households were selected based on type of cooking fuels (LPG/electric heater/ wood) and condition of kitchens (with or without exhaust fan / modular exhaust). Each household was further divided into three different sub sites (Kitchen, drawing rooms and bed rooms). Besides this at each site three one Room accommodation households using Chulha were selected.

At each site and sub-site sampling of the indoor, $PM_{2.5}$ was done thrice randomly on three different days by CPCB Gravimetric method (CPCB,2014) using Sioutas Personal Cascade Impactor with Leland Legacy Sampling Pump on Zefluor^{TM} supported PTFE filter paper of 0.5 micron pore size and 25 mmdiameter for eight hours at 9 lpm. The weighing of filter paper was done using Mettler Toledo micro balance Model MS105DU with sensitivity of 0.01 mg.

The concentration of the $PM_{2.5}$was determined by the formula:

$$\text{Conc. of } PM_{2.5}\ (\mu g/m^3) = \frac{(W_1-W_0) \times 10^6}{\text{Volume of air}} \quad \text{.........Eq. 1}$$

where, $W_1$and W_0 are Final and Initial weights of filter paper in mg.

Finally data was compiled to calculate average values with standard deviation.

RESULTS AND DISCUSSION

The critical analysis of households at Residential area revealed that the households with LPG as mode of Cooking fuel and kitchen without exhaust exhibited maximum indoor $PM_{2.5}$ of 110.33±47.57 µg/m^3 followed by households using LPG and Heater as mode of Cooking fuel and kitchen without exhaust exhibited indoor $PM_{2.5}$ of 104.90±10.92 µg/m^3 and minimum Indoor $PM_{2.5}$ of

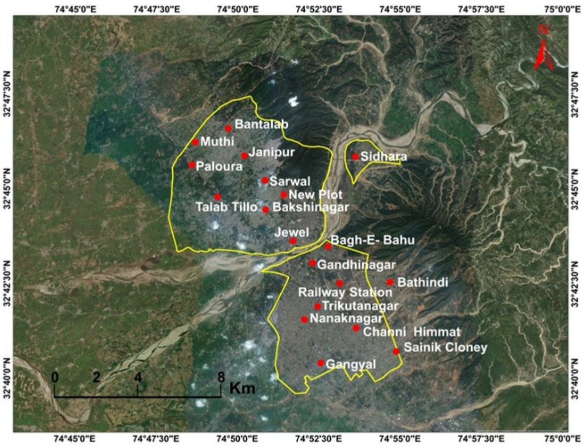

Fig. 1. *Map showing the study area (Municipal urban area of Jammu).*

Table 1. Indoor $PM_{2.5}$ in urban households of residential Sites in Jammu (J&K).

Mode of Cooking	Condition of Kitchen	*Indoor $PM_{2.5}$ in (µg/m^3) in			
		Kitchen	**Drawing Room**	**Bedroom**	**Households**
LPG	With Exhaust	71.75	67.12	60.185	66.35±5.82 (60.12-71.75)
LPG	Without Exhaust	106.48	64.81	159.72	110.33±47.57 (64.81-159.72)
LPG	Modular Exhaust	60.185	32.40	57.87	50.15±15.41 (32.40-57.87)
LPG/ Heater	With Exhaust	90.27	64.81	78.70	77.92±12.74 (64.81-90.27)
LPG/ Heater	Without Exhaust	113.42	108.7	92.59	104.90±10.92 (92.59-113.42)
LPG/ Heater	Modular Exhaust	78.70	48.61	64.81	64.04±15.05 (48.61-78.70)
Average in the study area		86.80±20.53 (60.185-113.42)	64.40±25.46 (32.40-108.7)	85.64±38.56 (57.87-159.72)	78.95±29.40 (32.40-159.72)

Permissible limits of $PM_{2.5}$ as prescribed by (CPCB, 2014) is 60µg/m^3

Table 2. Indoor $PM_{2.5}$ in urban households of commercial sites in Jammu (J&K).

Mode of Cooking	Condition of Kitchen	Indoor $PM_{2.5}$ in (µg/m^3) in			
		Kitchen	**Drawing Room**	**Bedroom**	**Households**
LPG	With Exhaust	136.57	78.70	83.33	99.53±32.15 (78.70-136.57)
LPG	Without Exhaust	141.20	90.27	122.68	118.05±25.77 (90.27-141.20)
LPG	Modular Exhaust	92.59	46.29	81.01	73.29±24.09 (46.296-92.59)
LPG/ Heater	With Exhaust	206.01	83.33	57.87	115.736±79.20 (57.87-206.01)
LPG/ Heater	Without Exhaust	159.72	113.42	145.83	139.65±23.75 (113.42-159.72)
LPG/ Heater	Modular Exhaust	118.055	76.38	69.44	87.95±26 .29 (69.44-118.055)
Average in the study area		142.35±38.61 (92.59-206.01)	81.39±21.78 (46.29-113.42)	93.36±33.75 (57.87-145.83)	105.7±40.61 (46.29-206.01)

Permissible limits of $PM_{2.5}$ as prescribed by (CPCB, 2014) is 60µg/m^3

Table 3. Indoor $PM_{2.5}$ in urban households of industrial sites in Jammu (J&K).

Mode of Cooking	Condition of Kitchen	Indoor $PM_{2.5}$ in ($\mu g/m^3$) in			
		Kitchen	**Drawing Room**	**Bedroom**	**Households**
LPG	With Exhaust	120.37	83.33	87.96	97.22±20.18 (83.33-120.37)
LPG	Without Exhaust	125.0	94.90	97.22	105.70±16.74 (94.90-125.0)
LPG	Modular Exhaust	81.01	39.35	46.29	55.55±22.32 (39.35-81.01)
LPG/ Heater	With Exhaust	122.68	83.33	94.90	100.30±20.22 (83.33-122.68)
LPG/ Heater	Without Exhaust	127.31	113.42	115.74	118.82±7.44 (113.42-127.31)
LPG/ Heater	Modular Exhaust	101.85	71.75	78.70	84.1±15.75 (71.75-101.85)
Average in the study area		113.03±18.13 (81.01-127.31)	81.01±24.80 (39.35-113.42)	86.80±23.32 (46.29-115.74)	93.61±25.36 (39.35-127.31)

Permissible limits of $PM_{2.5}$ as prescribed by (CPCB, 2014) is $60 \mu g/m^3$

Table 4. Indoor $PM_{2.5}$ in urban households in Jammu (J&K).

Sites	Indoor $PM_{2.5}$ in ($\mu g/m^3$) in			
	Household I	**Household II**	**Household III**	**Average Household**
Residential	115.74	118.05	122.68	118.82±3.53 (115.74-122.68)
Commercial	143.51	150.46	138.88	144.28±5.82 (138.88-150.46)
Industrial	155.09	162.03	152.77	156.63±4.81 (152.77-162.03)
Average in the Study Area	138.11±20.22 (115.74-155.09)	143.51±22.79 (118.05-162.03)	138.11±15.05 (122.68-152.77)	139.91±17.20 (115.74-162.03)

Permissible limits of $PM_{2.5}$ as prescribed by (CPCB, 2014) is 60 $\mu g/m^3$

50.15±15.41 $\mu g/m^3$ was exhibited by LPG using households with modular exhaust (Table 1).

The critical analysis of data of indoor $PM_{2.5}$ at Commercial area revealed LPG and Heater using households without exhaust exhibited maximum of 139.65±23.75$\mu g/m^3$indoor $PM_{2.5}$ followed by LPG using households without exhaust exhibiting indoor $PM_{2.5}$ of 118.05±25.77$\mu g/m^3$ and minimum Indoor $PM_{2.5}$ of 73.29±24.09$\mu g/m^3$ was exhibited by LPG using households with modular exhaust (Table 2).

The critical analysis of households at Industrial area revealed households without exhaust and using LPG and Heater for Cooking exhibited maximum indoor $PM_{2.5}$ of 118.82±7.44$\mu g/m^3$ followed by LPG and Heater using households with exhaust exhibiting indoor $PM_{2.5}$ of 100.30±20.22$\mu g/m^3$ and minimum Indoor $PM_{2.5}$ of 55.55±22.32$\mu g/m^3$ was exhibited by LPG using households with modular exhaust (Table 3).

In general, kitchens in all the households at all the sites exhibited higher values of indoor $PM_{2.5}$ as compared with that of bedroom and drawing rooms. This was due to emissions of more particulate matter in kitchens as well as smaller area as compared to bedroom and drawing rooms having larger area with less emissions of particulate matter.

The present observation that at all the sites households without exhaust exhibited maximum indoor $PM_{2.5}$followed by households with exhaust and minimum Indoor $PM_{2.5}$ was exhibited by households with modular exhaust supports the observation of (Parajuli *et al,* 2016) that the ventilation plays the vital role to control IAQ.

The analysis of data revealed that households located at Commercial area exhibited maximum indoor $PM_{2.5}$ of 105.7±40.61 $\mu g/m^3$ followed by households at Industrial area exhibiting indoor $PM_{2.5}$ of 93.61±25.36 $\mu g/m^3$ and minimum indoor $PM_{2.5}$ of 78.95±29.40 $\mu g/m^3$ was exhibited by households at Residential area (Tables 1-3). This analysis suggested that outdoor location of Households also had impact on the Indoor $PM_{2.5.}$

The analysis of data further revealed that One Room accommodation Households using Chulha at all the sites exhibited more Indoor $PM_{2.5}$ as compared with households even without exhaust. Analysis of data of Indoor $PM_{2.5}$ at one Room accommodation revealed that households with Chulha exhibited maximum Indoor $PM_{2.5}$ of 156.63±4.81 $\mu g/m^3$ at Industrial Site followed by 144.28±5.82 $\mu g/m^3$ at Commercial site and minimum of 118.82±3.53 $\mu g/m^3$at Residential Site (Table 4). This again suggested that outdoor sources of $PM_{2.5}$ also had impact on the Indoor $PM_{2.5.}$

Overall compilation of data revealed that average urban Household irrespective of mode of cooking fuel and its location exhibited average 92.75±33.68

indoor $PM_{2.5}$whereas average indoor $PM_{2.5}$ in One Room accommodation with Chulha. Households was observed to be 139.91±17.20 µg/m^3. The present observation supports the earlier work of Mukkannawar *et al* (2014) who reported that Indoor $PM_{2.5}$ in the Kerosene and LPG using households was comparatively less than that of chulha using households.

Smith (2002) reported that residents in majority of households in developing countries rely on solid fuels (coal or biomass as wood, crop residues, and dung) suffer from substantial ill-health due to indoor air pollution (IAP) from household cooking and space heating Laden *et al*(2006)reported evidence of increase in the long term effects on lung health due to relatively low levels of exposure to particulate pollution. Bruce *et al.* (2000) also reported that residents in majority of households in developing countries rely on solid fuels and consequently, women and young children were exposed to high risk of chronic obstructive pulmonary disease and of acute respiratory infections. Lin *et al.* (2018) highlighted the fact that in China due to absence of the indoor $PM_{2.5}$ pollution concentration prescribed limits, it was difficult to establish monitoring network on indoor air $PM_{2.5}$, though it was more closely related to human health. he average indoor $PM_{2.5}$ in all the sampled urban households of Jammu was observed to be 99.49±35.84 µg/m^3 which is above the permissible limit of $PM_{2.5}$ as prescribed by CPCB (2014).

Conclusion

The average indoor $PM_{2.5}$ in all the sampled urban households of Jammu was observed to be 99.49±35.84 µg/m^3 which is above the permissible limits of $PM_{2.5}$ as prescribed by CPCB (2014). The data generated in present study will act as base line data for further studies pertaining to its ionic analysis as well as suggesting mitigation measures to improved mode of Cooking and architectural design of Households to minimise the exposure of Residents to Indoor $PM_{2.5.}$

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