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Research Article

Seasonal variations of indoor aerosols ($PM_{2.5}$) in urban households of Jammu (J&K), India

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Abstract
Indoor pollution is more harmful as people spend more than 90% of their time indoors getting enhanced chances of penetrating aerosols ($PM_{2.5}$) deeply into the lungs. In the present investigation, an attempt has been made to study seasonal variations of indoor aerosols ($PM_{2.5}$) in urban households of Jammu(J&K). in the northern region of India. The status of indoor aerosols ($PM_{2.5}$) and their seasonal variations due to temperature and humidity conditions have been studied for the first time in urban households of Jammu (J&K). The two year study period (2017-2019.) revealed that all types of households of urban areas with non-wood fuel as well as wood fuel burning practices exhibited significantly ($p<0.05$) higher values of indoor $PM_{2.5}$ during summer season (74.36 μg/m^3 and 156.46 μg/m^3) followed by winter season (62.77 μg/m^3 and 143.5μg/m^3) and lower values during the rainy season (58.47 μg/m^3 and 132.52 μg/m^3). All these values were observed to be above the CPCB prescribed annual limit of 40 μg/m^3, thereby exposing the residents to diseases of the respiratory and cardiovascular systems. The data generated in the present study will act as baseline data for future studies pertaining to indoor aerosols ($PM_{2.5}$) as well as suggesting mitigation measures.

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

INTRODUCTION

One of the most important environmental issues has been reported to be particulate air pollution which adversely affects health. As per the estimate of The Global Burden of Disease Study (2021), indoor air pollutants due to inefficient and incomplete combustion of solid fuel (SF)has been reported to be responsible for 3.55 million deaths, with higher risks in women and children, due to their higher exposure duration and unique physical properties. (Ali *et al.,* 2021). The short-term effects of particulate matter on the respiratory system have been manifested as stimulation and corrosion of the alveolar wall, damaging the respiratory and lung function resulting in cough, expectoration, wheezing, and chronic bronchitis emphysema, chronic obstructive pulmonary disease (COPD) and other diseases (Huang *et al.,*2018). The use of fire for cooking and warming was the prehistoric times of the start of air pollution. Air pollution is increasing at an alarming rate today due to the addition of harmful chemicals into the Earth's atmosphere (Fullerton *et al.* (2008)

India's current population has been reported to be 1.34 billion (www.indianonlinepages.com), but about 89% of rural India has been reported to use biomass for cooking purposes and urban India has been reported to use mainly LPG, which is reported to meet demands up to 64% in urban India. Dung cake, kerosene, coke, fire chips and other fuel resources are reported to meet demand upto1%,7%,2%,18% and 8%, respectively, in urban India (PHFI, 2017). Besides outdoor sources and cooking sources, various chemicals in cleaning supplies, building products, furniture and carpeting, pet dander, mould, bacteria, dust mites and even radon gas are additional sources of particulate matter in our indoor spaces (Smith, 2000). Particulate matter has been reported to exhibit variations during different seasons at residential, commercial and industrial sites (Shukla and Sharma, 2008; Kamath and Lokeshappa, 2014; Ni et al., 2016; Cheng and Wang-Li, 2019). In the present investigation, an attempt was made to study seasonal variations of indoor aerosols ($PM_{2.5}$) in Jammu (J&K) urban households during the two year study period of 2017-2019.

MATERIALS AND METHODS

Study area

The study was conducted in an Urban area (U) (within the municipal area) of Jammu (J&K). The study area was divided into three Sub-areas: 1) Residential area (R), 2) Commercial area (C) and 3) Industrial area (I). Each site was further divided into seven sites based on the kitchen's cooking fuel and ventilation conditions (Fig.1).

1. Sites of Residential area (UR):

i) URLE (Urban Residential LPG Exhaust)
Household with LPG as a mode of cooking fuel and exhaust in the kitchen. This house was located in the residential area (Nanak Nagar),

ii) URLWE (Urban Residential LPG without Exhaust)
Household with LPG as mode of cooking fuel and without exhaust in the kitchen. This house was located in residential area (Muthi),

iii) URLM (Urban Residential LPG Modular)
Household with LPG as a cooking fuel and modular kitchen mode. This house was located in residential area (Channi),

iv) URLHE (Urban Residential LPG Heater Exhaust)
Household with LPG –Heater (Induction) as mode of cooking and exhaust in the kitchen. This house was located in residential area (Newplot).

v) URLHWE (Urban Residential LPG Heater without Exhaust)
Households with LPG –Heater (Induction) as a mode of cooking fuel and without exhaust in the kitchen. This house was in a residential area (Rehari),

vi) URLHM (Urban Residential LPG Heater Modular)
Households with LPG –Heater (Induction) as a mode of cooking fuel and modular kitchen. This house was located in a residential area (Janipur),

vii) URC (Urban Residential Chullah)
Households with Wood fuel burning (Chullah) as a mode of cooking. This house was located in a residential area (Muthi).

2. Sites of Commercial area (UC):

i) UCLE (Urban Commercial LPG Exhaust)
Household with LPG as mode of cooking fuel and exhaust in the kitchen. This house waslocated in commercial area (Newplot)

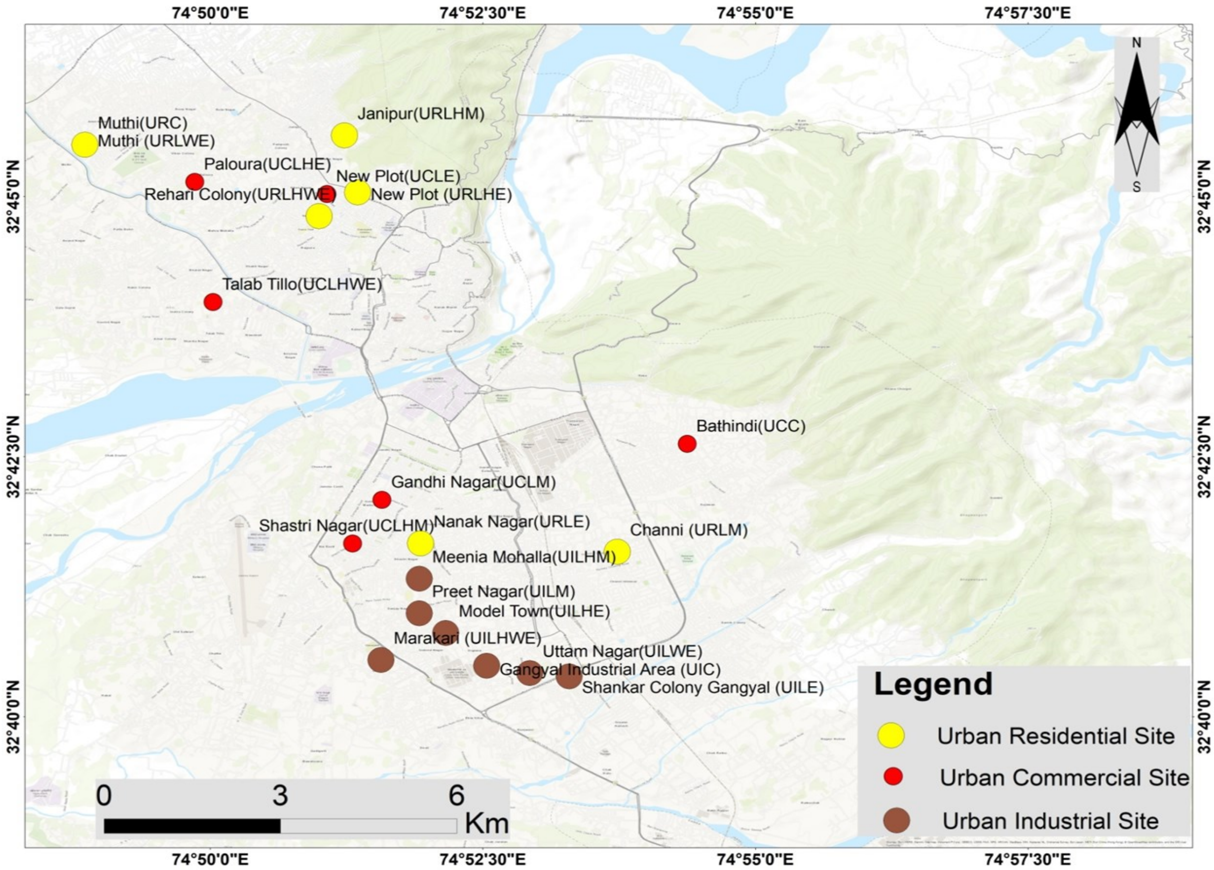

Fig.1. *Map showing different sites of the study area (Jammu Municipal Limits).*

ii) UCLWE ((Urban Commercial LPG without Exhaust): Household with LPG as mode of cooking fuel and without exhaust in the kitchen. This house was located in a commercial area (Bantalab)

iii) UCLM (Urban Commercial LPG Modular) : Household with LPG as mode of cooking fuel and modular kitchen. This house was located in a commercial area (Gandhi Nagar),

iv) UCLHE (Urban Commercial LPG Heater Exhaust)
Household with LPG- Heater (Induction) as a mode of cooking and exhaust in the kitchen. This house was located in a commercial area (Paloura)

v) UCLHWE (Urban Commercial LPG Heater without Exhaust)
Household with LPG –Heater (Induction) as mode of cooking fuel and without exhaust in the kitchen. This house was located in a commercial area (TalabTillo),

vi) UCLHM ((Urban Commercial LPG Heater Modular) Households with LPG –Heater (Induction) as a mode of cooking fuel and modular kitchen. This house is located in a commercial area (Shastri Nagar),

vii) UCC (Urban Commercial Chullah)
Household with Wood fuel burning (Chullah) as mode of cooking. This house was in a commercial area (Bathindi).

3. Industrial sites of Urban area (UI):

i) UILE (Urban Industrial LPG Exhaust)
Households with LPG as mode of cooking fuel and exhaust in the kitchen. This house was located in an industrial area (Shankar Colony Gangyal)

ii) UILWE-(-**(Urban Industrial LPG without Exhaust)**
Household with LPG as a mode of cooking fuel and without exhaust in the kitchen. This house was located in an industrial area (Uttam Nagar)

iii) UILM (Urban Industrial LPG Modular)
Household with LPG as a mode of cooking fuel and modular kitchen. This house was located in an industrial area (Preet Nagar)

iv) UILHE (Urban Industrial LPG Heater Exhaust)
Household with LPG –Heater (Induction) as mode of cooking and exhaust in thekitchen. This house was located in industrial area (Model Town)

v) UILHWE (Urban industrial LPG heater without exhaust)
Household with LPG –Heater (Induction) as a mode of cooking fuel and without exhaust in the kitchen. This house was located in industrial area (Marakri, Industrial area)

vi) UILHM (Urban Industrial LPG Heater Modular)
Household with LPG –Heater (Induction) as a mode of cooking fuel and modular kitchen. This house was located in industrial area (Meenia Mohalla),

vii) UIC (Urban Industrial Chullah)
Household with Wood fuel burning (Chullah) as a mode of cooking. This house was located in an industrial area (Gangyal Industrial Area Phase 2) (Fig.1).
The indoor air sampling was done to assess the concentration of the indoor $PM_{2.5}$ during the summer (March-June), winter (November-February) and rainy seasons(July-October) of the two-year study period (July 2017- June 2019) at selected sites of the Jammu district. At each site, the sampling of indoor $PM_{2.5}$ was done thrice (once each in Kitchen, drawing room and bed room of two room accommodation and thrice in same one-room accommodation on three consecutive days) by following the Gravimetric method prescribed by the Central Pollution Control Board (2014) using Sioutas Personal Cascade Impactor with Leland Legacy Sampling Pump on Zefluor^{TM} supported with PTFE filter paper of 0.5 micron pore size and 25 mm. diameter for 24 hours at 9 lpm. The weighing of filter paper was made using Mettler Toledo Microbalance Model MS105DU with a sensitivity of 0.01 mg.
The concentration of the $PM_{2.5}$ was determined by the formula:

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

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 and all the data was statistically analysed by One-way ANOVA and Post Hoc Test using IBM SPSS Statistics Version 22.

RESULTS AND DISCUSSION

$PM_{2.5}$ variations among different types of households with non-wood fuel burning practice at Urban Residential Sites i.e. URLE, URLWE, URLM, URLHE, URLHWE and URLHM, Urban Commercial Sites, i.e. UCLE, UCLWE, UCLM, UCLHE, UCLHWE and UCLHM; and Urban Industrial Sites i.e. UILE, UILWE, UILM, UILHE, UILHWE and UILHM were observed to be insignificant ($p>0.05$) except households with Modular kitchen at all urban sites, i.e. URLM at urban residential sites, UCLM at urban commercial sites, UILM at urban industrial sites which exhibited significant ($p<0.05$) lowest values of indoor aerosols($PM_{2.5}$) as

Table 1. Indoor $PM_{2.5}$ levels in urban residential sites of study area during different seasons.

SITE	$PM_{2.5}$ µg/m^3			
	Summer	**Rainy**	**Winter**	**One-way ANOVA (season wise) Significance value (p)**
URLE	57.96±11.98 (46.89-74.07)	35.83±13.54 (23.14-54.39)	44.01±11.91 (34.72-60.64)	0.034
URLWE	76.44±15.12 (64.81-96.90)	62.03±9.16 (50.92-72.45)	67.28±15.08 (52.31-86.11)	0.023
URLM	46.40±12.12 (32.40-61.57)	30.74±11.04 (18.51-44.44)	38.34±9.92 (25.46-49.07)	0.043
URLHE	74.22±8.88 (64.58-86.11)	45.56±9.21 (34.72-56.71)	54.23±7.74 (46.75-65.27)	0.033
URLHWE	81.59±13.47 (70.60-99.53)	65.73±11.53 (53.24-80.78)	72.60±15.19 (57.87-93.05)	0.023
URLHM	53.69±8.82 (43.51-65.27)	35.73±11.49 (20.92-48.14)	40.08±13.36 (27.77-58.33)	0.039
URC	124.64±1.86 (122.24-12587)	116.26±0.73 (115.21-116.82)	118.64±0.83 (118.21-119.82)	0.023

CPCB prescribed annual limit of 40 µg/m^3 ; URLE- Households with LPG as mode of cooking fuel and exhaust in the kitchen; URLWE- Households with LPG as mode of cooking fuel and without exhaust in the kitchen. URLM- Households with LPG as mode of cooking fuel and modular kitchen; URLHE- Households with LPG –Heater (Induction) as mode of cooking and exhaust in the kitchen.; URLHWE - Households with LPG –Heater as mode of cooking fuel and without exhaust in the kitchen; URLHM- Households with LPG –Heater (Induction) as mode of cooking fuel and modular kitchen; URC- Households with Wood fuelburning (Chullah) as mode of cooking.

Table 2. Indoor $PM_{2.5}$ levels in Urban commercial sites of study area during different seasons.

SITE	$PM_{2.5}$ µg/m^3			
	Summer	**Rainy**	**Winter**	**One-way ANOVA (season wise) Significance value(p)**
UCLE	87.72±9.47 (78.70-101.85)	67.12±11.66 (57.87-83.10)	70.86±13.30 (59.72-88.88)	0.031
UCLWE	90.65±18.58 (69.44-113.19)	71.33±14.52 (60.18-91.89)	74.37±14.26 (62.03-93.51)	0.023
UCLM	59.33±11.61 (46.29-75.00)	48.99±13.29 (37.03-66.89)	53.77±13.85 (40.27-72.68)	0.037
UCLHE	93.39±18.36 (77.77-118.05)	73.64±13.68 (62.50-92.12)	76.26±14.21 (64.81-95.83)	0.034
UCLHWE	98.72±18.88 (81.48-123.84)	80.42±14.48 (68.51-100.69)	82.21±13.66 (71.52-100.46)	0.023
UCLHM	70.90±10.49 (59.25-85.18)	55.08±10.18 (46.29-68.98)	58.86±10.75 (48.61-72.68)	0.043
UCC	169.6±9.5 (162.4-176.8)	138.93±7.62 (133.25-144.18)	154.19±5.28 (150.25-157.18)	0.024

CPCB prescribed annual limit of 40 µg/m^3 UCLE- Households with LPG as mode of cooking fuel and exhaust in the kitchen. UCLWE- Households with LPG as mode of cooking fuel and without exhaust in the kitchen. UCLM- Households with LPG as mode of cooking fuel and modular kitchen.,UCLHE- Households with LPG –Heater (Induction) as mode of cooking and exhaust in the kitchen.UCLHWE- Households with LPG –Heater (Induction) as mode of cooking fuel and without exhaust in the kitchen. UCLHM- Households with LPG –Heater (Induction) as mode of cooking fuel and modular kitchen.UCC- Households with Wood fuel burning (Chullah) as mode of cooking.

compared with respective residential, commercial and industrial sites during summer, rainy and winter seasons of two year study period (Tables 1-3). Modular exhaust in URLM,UCLM and UILM households was observed to be responsible for significant ($p<0.05$) lowest values of indoor aerosols($PM_{2.5}$) and this observation was supported by the findings of Parajuli *et al.* (2016) who reported that the ventilation played the vital role to control Indoor Air Quality (IAQ) and recommended a greater focus on ventilation.

The critical analysis of urban households with non-wood fuel-burning practice revealed that among Urban

Table 3. Indoor $PM_{2.5}$ levels in Urban industrial sites of study area during different seasons.

SITE	$PM_{2.5}$ μg/m^3			
	Summer	**Rainy**	**Winter**	**One-way ANOVA (season wise) Significance value(p)**
UILE	77.05±12.58 (62.96-92.82)	63.32±12.53 (53.24-80.55)	66.77±15.02 (55.32-86.80)	0.033
UILWE	82.24±14.79 (65.74-100.64)	67.04±11.06 (57.87-82.40)	70.63±16.38 (56.48-92.36)	0.031
UILM	51.61±12.83 (39.35-68.51)	46.94±11.92 (34.95-63.42)	49.41±10.35 (38.42-62.96)	0.035
UILHE	82.05±10.27 (68.98-93.75)	72.95±12.24 (61.80-88.88)	75.69±13.75 (62.96-93.75)	0.032
UILHWE	91.12±12.15 (79.86-107.63)	76.00±13.44 (64.35-93.51)	79.89±13.71 (68.51-98.37)	0.036
UILHM	63.42±7.77 (55.55-74.30)	54.16±9.97 (43.98-68.05)	55.04±8.06 (46.75-65.97)	0.039
UIC	175.16±9.5 (170.25-179.18)	142.37±7.62 (139.25-145.18)	157.67±2.32 (156.25-159.18)	0.031

CPCB prescribed annual limit of 40 μg/m^3 ;UILE- Households with LPG as mode of cooking fuel and exhaust in the kitchen; UILWE- Households with LPG as mode of cooking fuel and without exhaust in the kitchen; UILM- Households with LPG as mode of cooking fuel and modular kitchen;UILHE- Households with LPG –Heater (Induction) as mode of cooking and exhaust in the kitchen. This house is in industrial area (Model Town);UILHWE- Households with LPG –Heater (Induction) as mode of cooking fuel and without exhaust in the kitchen;UILHM- Households with LPG –Heater (Induction) as mode of cooking fuel and modular kitchen.; UIC- Households with Wood fuelburning (Chullah) as mode of cooking.

Residential Sites (URLE, URLWE, URLM, URLHE, URLHWE and URLHM), URLHWE exhibited the highest value of 81.59±13.47μg/m^3, among Urban Commercial Sites (UCLE, UCLWE, UCLM, UCLHE, UCLHWE and UCLHM), UCLHWE exhibited the highest value of 98.72±18.88 μg/m^3 and among Urban Industrial Sites (i.e. UILE, UILWE, UILM, UILHE, UILHWE and UILHM), UILHWE exhibited the highest value of 91.12 ±12.15μg/m^3 during the summer season which was above the CPCB prescribed annual limit of 40 μg/m^3 thereby exposing the residents to the probability of diseases of the respiratory and cardiovascular systems as per Pozzer *et al.* (2019) who concluded that 11.3% of the total deaths due to diseases of the respiratory and cardiovascular systems were attributable to long-term exposure to $PM_{2.5}$ pollution. During the rainy season, which was below the CPCB prescribed annual limit of 40 μg/m$^{3.}$

Among Residential sites, URLM exhibited the lowest value of 30.74±11.04μg/m^3, among Commercial sites, UCLM exhibited the lowest value of 48.99±13.29μg/m^3 during the rainy season, which was below the CPCB prescribed annual limit of 40 μg/m^3 whereas among Industrial sites. UILM exhibited the lowest value of 46.94±11.92μg/m^3 during the rainy season which was above the CPCB prescribed annual limit of 40 μg/m^3. Kamath and Lokeshappa (2014), while investigating air pollutant concentration at residential, industrial and sensitive areas of Bangalore, also observed that concentration of pollutants was more in summer than in pre -monsoon and post-monsoon monsoon seasons.

The analysis of compiled data of indoor $PM_{2.5}$ during different seasons of two year study period revealed that all types of households of urban areas with non-wood fuel burning practice exhibited significantly ($p<0.05$) higher values of indoor $PM_{2.5}$ during the summer season(74.36±9.20 μg/m^3) followed by winter season (62.77±8.81 μg/m^3) and then the lower values during rainy season (58.47±10.94 μg/m^3) (Table 4). Humidity and penetration of outdoor $PM_{2.5}$ could be the reason for seasonal variability. Low humidity and dry air during summer with the accumulation of more outdoor $PM_{2.5}$ due to the working of dessert coolers, air conditioners and opening of windows during electric failure has been observed to be the cause of higher $PM_{2.5}$ during summer. This observation finds support from the work of Yang *et al.* (2018), who reported that outdoor concentration was an important factor for indoor $PM_{2.5.}$ and that Shao *et al.* (2019) reported the penetration of the particles from the ambient environment as a major source of indoor $PM_{2.5}$ pollution. Consequently, the closer of windows and non-working of dessert coolers, air conditioners restricted the entry of outdoor $PM_{2.5,}$ thereby decreasing the values of indoor $PM_{2.5}$ during winter and very high humidity during the rainy season was observed to be the cause of lowest indoor $PM_{2.5}$.

Shukla and Sharma (2008), while studying the seasonal variability in ambient aerosols over Kanpur, also observed the lowest concentration of PM_{10} during the monsoon period and higher variability in summers because of higher wind speed in summers. Cheng and Wang-Li (2019), while carrying out spatial and temporal variations of $PM_{2.5}$ in north Carolina, also reported $PM_{2.5}$ concentrations higher in summer and lower in the winter.

The analysis of compiled data of indoor aerosols ($PM_{2.5}$) revealed that all types of urban households with non-wood fuel-burning practice at commercial sites exhibited significantly ($p<0.05$) higher values of indoor $PM_{2.5}$ as compared with that of industrial sites followed by residential sites during all the seasons of two year study period (Tables1-3). Commercial areas were observed to have more complex anthropogenic activities, thereby emitting more particulate matter than industrial and residential areas. As already discussed, the more the outdoor $PM_{2.5}$, the more would be indoor $PM_{2.5}$ as reported by Yang *et al.* (2018) in Beijing and Shao *et al.* (2019) in Nanjing, China

Indoor $PM_{2.5}$ variations among different types of households with wood fuel burning practice (Chullah) at Urban Residential Sites (URC), Urban Commercial Sites (UCC), Urban Industrial Sites (UIC) were also observed to be insignificant ($p>0.05$) during a specific season. But households at Urban Residential Sites (URC), Urban Commercial Sites (UCC) and Urban Industrial Sites (UIC) exhibited significantly ($p<0.05$) higher values of indoor $PM_{2.5}$ during the summer season (156.46±27.70 µg/m^3), followed by winter season (143.5±21.59 µg/m^3) and lowest during rainy seasons (132.52±14.18 µg/m^3) of two year study period (Tables 1-3). But all these values were observed to be well above the CPCB prescribed annual limit of 40 µg/m. Overall compilation of indoor $PM_{2.5}$ data of all types of households of study area revealed that households with wood fuel burning practice (Chullah) exhibited significantly ($p<0.05$) higher value (144.09±21.28µg/m^3) of indoor $PM_{2.5}$ as compared with the value (65.20±9.51 µg/m^3) of households with non-wood fuel burning practice (Table 4). Parajuli *et al.* (2016) also reported higher indoor $PM_{2.5}$ concentration (1336 lg/m^3) for Traditional Cooking Stoves (TCS) and lower indoor $PM_{2.5}$ concentration (825.4 ± 730.9 lg/m$^{3)}$) for Improved Cooking Stove (ICS). The present observation that indoor $PM_{2.5}$ of households with wood fuel burning practice (Chullah) exhibited 2.2 times higher value as compared with households with non-wood fuel-burning practice supports the observation of Deepthi *et al.* (2018) reporting the PM concentrations in biomass households as 2.1 and 3.8 times of combination of biomass and LPG and; only LPG respectively. Moreover, smoke emitted from biomass had significantly high concentrations of toxic chemicals and particulate matter,

Table 4. Average indoor aerosols ($PM_{2.5}$) levels in Non wood fuel burning households and wood fuel burning households of Jammu during different seasons of two year study period.

Site	Average indoor aerosols ($PM_{2.5}$) µg/m^3								
	Summer (Non wood fuel)	Summer (wood fuel)	Rainy (Non wood fuel)	Rainy (wood fuel)	Winter (Non wood fuel)	Winter (wood fuel)	Two years Study period (Non wood fuel)	Two year study period (wood fuel)	Average Two Year Study Period
Residential	65.05±17.21 (32.40-99.53)	124.64±1.86 (122.24-125.87)	45.94±17.09 (18.51-80.78)	116.26±0.73 (115.21-116.82)	52.76±17.72 (25.46-93.05)	118.64±0.83 (118.21-119.82)	54.58±9.68 (18.51-99.53)	119.63±3.68 (115.74-125.35)	87.21±36.36 (18.51-125.35)
Commercial	83.45±19.79 (46.29-123.84	169.6±9.5 (162.4-176.8)	66.09±16.34 (37.03-100.69	138.93±7.62 (133.25-144.18)	69.33±15.97 (40.27-100.46)	154.19±5.28 (150.25-157.18)	72.95±9.23 (23.61-123.84)	154.24±14.94 (133.51-176.32)	113.59±45.93 (23.61-176.32)
Industrial	74.58±17.36 (39.35-107.63)	175.16±9.5 (170.25-179.18)	63.40±15.09 (34.95-93.51)	142.37±7.62 (139.25-145.18)	66.24±16.42 (38.42-98.37)	157.67±2.32 (156.25-159.18)	68.07±5.81 (24.53-107.63)	158.40±15.11 (139.09-179.56)	113.23±50.68 (24.53-179.56)
Average	74.36±9.20 (32.40-123.84)	156.46±27.70 (122.24-179.18)	58.47±10.94 (18.51-100.69)	132.52±14.18 (115.21-145.18)	62.77±8.81 (25.46-100.46)	143.5±21.59 (118.21-159.18)	65.2±9.51 (18.51-123.84)	144.09±21.28 (115.74-179.56)	104.68±44..33 (18.51-179.56)

CPCB prescribed annual limit of 40 µg/m^3;One-way ANOVA (site and season wise) variations Significant($p<0.05$); Average Indoor aerosols ($PM_{2.5}$) level in Non wood fuel burning households and wood fuel burning households during two year study period was calculated to be 65.20±9.51µg/m^3 and 144.09±21.28µg/m^3 ;Overall Average Indoor aerosols ($PM_{2.5}$) level in Study area during two year study period was calculated to be 104.68±44.33.

which was responsible for numerous respiratory health syndromes – particularly in women and children who used to spend the most time at home cooking, as reported by Roshan and Isaifan (2018) while reviewing health hazards of air pollution from burning biomass for cooking and heating in Asia and Africa and Paulsen *et al.* (2019). in rural Guatemala

The present observation that indoor $PM_{2.5}$ of households with wood fuel burning practice exhibited 2.6 times higher value and households with non-wood fuel burning practice exhibited 1.6 times higher value as compared with CPCB prescribed annual limit of 40 µg/m^3 supports the findings of Pokhrel *et al.* (2015) who observed the mean household $PM_{2.5}$ concentrations during all seasons of the year as 656 mg/m^3 from biomass, 169 mg/m^3 from kerosene; 101 mg/m^3 from LPG; and 80 mg/m^3 from electric stoves and these were observed to be 11, 2.8, 1.7 and 1.3 times higher as compared with Nepal's national 24-h indoor air quality standard for $PM_{2.5}$ (60 mg/m3).

Compilation of data of indoor $PM_{2.5}$ of households with wood fuel burning practice and households with non-wood fuel burning practice exhibited significantly ($p<0.05$) highest value (115.4µg/m^3) of indoor $PM_{2.5}$ during summer seasons followed by winter season (103.1 µg/m^3) and lowest during rainy seasons (95.5 µg/m^3) of two year study period with overall average indoor $PM_{2.5}$ value of 104.68±44..33 µg/m^3 (Table 4) thereby exposing the residents to diseases of the respiratory and cardiovascular systems due to long-term exposure to $PM_{2.5}$ pollution. as reported by Pozzer *et al.* (2019) . in Verona, Italy

Conclusion

Average indoor aerosols ($PM_{2.5}$) in wood fuel burning urban households of Jammu exhibited a value (144.09±21.36µg/m^3) almost two times higher than the value (65.20µg/m^3) of non-wood fuel-burning urban households of Jammu. Average indoor aerosols ($PM_{2.5}$) exhibited the highest value (115.4µg/m^3) during summer seasons followed by winter season (103.1 µg/m^3) and lowest during rainy seasons (95.5 µg/m^3) of two year study period with overall average indoor $PM_{2.5}$ value of 104.68±44..33 µg/m^3 thereby exposing the residents to diseases of the respiratory and cardiovascular systems due to long-term exposure to $PM_{2.5}$ pollution. . Variations in indoor aerosols values among various types of households (except at Household with modular kitchen) at each area during 1st year as well as 2ndwere observed to be insignificant ($p>0.05$) whereas areas wise and season wise variations in data were observed to be significant ($p<0.05$) as depicted by One-way ANOVA and Post Hoc Test. Wood fuel burning for cooking should be totally replaced by non-wood burning fuels as wood fuel burning urban households exhibited 2.2 times higher value of indoor aerosols than that of non-wood fuel-burning urban households of Jammu.

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Conflict of interest

The authors declare that they have no conflict of interest.

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