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Chapter

Influence of Microenvironments and Personal Activities on Personal PM$_{2.5}$ Exposures among Children and Adults

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Abstract

Environmental issues are a major worldwide problem of significant concern. Due to the growing human population and advancement in every sector, the environmental related issues are multiplying in recent years. Scalable exposures assessments approach that captures personal exposure to particles for purposes of epidemiology are currently limited, but very valuable especially for a country like India. The high levels of indoor particulate matter and the apparent scale of its impact on the global burden of disease underline the importance of particulate as an environmental health risk and the need for monitoring them. Human exposure especially to fine particles can have significant harmful effects on the respiratory and cardiovascular system. To investigate daily exposure characteristics to PM$_{2.5}$ with ambient concentrations in an urban environment, personal exposure measurements were conducted for different age groups of people residing in different indoor environments. To account for PM$_{2.5}$ exposure and measurements personal environment monitors (PEM) and medium volume sampler APM 550 was used to measure PM$_{2.5}$ concentration. On comparing the annual average PM$_{2.5}$ concentration with National Ambient Air Quality and WHO standards the concentrations were found to be many folds higher for personal and ambient monitoring at homes, schools, and offices. Moreover, the questionnaire data study explains the fact that the health hazards experienced by occupants linked to various activity patterns pose a greater risk in different indoor environments as compared to outdoor environments. The presented research method and analysis can help develop environmental awareness in identifying these pollutants and can also help in elucidating these contaminants. A real understanding of these possible causes of airborne contaminant is crucial for selecting and developing suitable and effective control methods.

Keywords: personal exposure monitoring, PM$_{2.5}$, indoor air quality

1. Introduction

Indoor air quality in sensitive areas like homes and public places has caught the interest not only of scientists but of the general public as well. Increasing public awareness is focusing on this issue as more and more individuals spent time inside than outside, particularly those who are most susceptible to the effects of poor air

quality, such as the elderly, the young, and those with poor health [1, 2]. A series of epidemiological studies reported that there are robust associations between short-term and long-term exposure to fine particles (particulate matter with a diameter less than $PM_{2.5}$ μm), they are responsible for harmful effects on human health, including cardiac and respiratory diseases. The American Cancer Society has noticed that for every 10 μg/m^3 increase in $PM_{2.5}$, a 6% increased risk of mortality and morbidity, which have recently increased to 10%, resulting in premature deaths, according to California Air Resource Board [3].

Mostly all individuals are potentially affected, but as a subpopulation child are more prone to suffer health effects due to surrounding emission sources [4]. Since their lung structure and immune system are not fully developed and have a higher metabolic rate than adults, which means that they breathe in more air per unit of body weight and are generally more susceptible to the effects of indoor air pollutants. Studies have reported an association of pupil's health with both school and domestic exposure [5, 6]. These pollutants may emanate from a variety of sources (building and construction materials and furnishings, building occupants and activities, inadequate building design, lack of maintenance), including the infiltration of outdoor pollutants, such as dust, soil, and fuel consuming products and internally from smoking, cooking, incense burning, building, and furniture materials, consumer products, shed skin cells and organic fibers. Therefore, children's personal exposures to air pollutants differ from that of adults. Nowadays the highest importance is attributed to aerosols, especially fine particles because they represent a complex mixture of organic and inorganic substances with potentially toxic, carcinogenic, inflammatory, allergens, and other adverse properties. Furthermore, varied sources of PM results in an extensive range of particle sizes, i.e., the lesser the diameter size, the further deeply it will deposit in the respiratory tract. In the nasal-breathing mode, the mucus and cilia act as a very particle deposition inside the respiratory area depend not only on particle characteristics, but also human physiology, i.e., is the individual's behavior throughout the day like breathing deeply. Personal monitoring is the most accurate approach for determining direct exposure to airborne environmental contaminants because it incorporates complex human activity patterns into the exposure assessment. Only a few data are available on personal measurements of fine particles and its characterization of chemical species is lacking in comparative studies for both adults and children's activity patterns in different microenvironments which is important for developing a regulatory outline.

Thus the present study aimed to pinpoint the integrated actions essential to reduce the particulate pollutant and eliminate the toxicological environmental impacts of the urban environment. Identification of sources and controls of this location may allow for better protection for adults and children's health and understanding to control them.

2. Site description

Agra (27°10'N, 78°05'E,) is situated in the state of Uttar Pradesh in India. It is surrounded by the Thar Desert in its south-east, west, and north-west peripheries and is therefore, it's a semiarid area. Agra experience three different seasons; summer (March–June), monsoon (July–October), and winter (November–February) in a year. In the summer period Agra experiences hot weather with dry westerly winds. During this time temperature ranges between 30–46°C. The relative humidity is quite low between 18% and 48% during this time duration. In the monsoon it is hot and humid, temperature varieties from 24 to 36° C, and the humidity varieties

Figure 1.
Site map of Agra showing major regions, roads, and highways and sampling sites. Two homes, two schools, two offices.

from 70–90%. The pre-monsoon and monsoon periods experience strong north-east and southeast winds and in the winter, the temperature varies from 5–25°C. Thunderstorms and dust storms are frequently observed during the months from March to June. The wind speeds diverge from 2.6 to 6.9 Km/h with a maximum during summer and monsoons and a minimum in winters [7]. Agra is the one of the most populated cities in Uttar Pradesh, India. Agra has a population of about 1.5 million (Females = 47% and Males = 53%), with a birth rate of 28/1000 people and a death rate of 7/1000 people (Agra Nagar [8]). Tones of solid wastes are generated every day that can be seen in the form of piles along roadsides and streets due to poor municipal services. It is also a major cause for adding contamination to soil and groundwater. In the present study, personal and ambient monitoring was carried out for PM$_{2.5}$ in three different locations (two homes, two schools, and two offices) in the city of Agra (**Figure 1**).

3. Sampling sites

Two homes were selected in different colonies of the urban area of the city Agra, personal and ambient monitoring was done throughout the study. In the urban colonies, there is usually the old type of houses, having parking garages inside their houses or beneath the house due to lack of spaces. The houses are very near to each other making the environment very congested which is believed to be due to lack of proper planning. Adults were selected especially women, for personal sampling at homes as they spend most of their time indoors. Similarly, two schools were selected adjacent to roads in the city of Agra. Near schools usually, their environment is of high traffic during the morning and late afternoon hours when the schools get over. Personal and ambient monitoring was also carried out here during the study period. Different children were selected for personal sampling at schools. Similarly, two offices were selected in the commercial areas of the city of Agra. The offices are situated adjacent to a busy road in the city which experiences heavy traffic throughout the day. Personal and ambient monitoring was also carried out here during the study period. Different adults were selected for personal exposure monitoring carrying out routine activities in the offices and during their outdoor visits (**Figure 2**).

Figure 2.
Sampling done at homes, schools and offices.

4. Sampling and analytical method

The study was conducted from December 2013 to February 2015 to determine the mass concentration of $PM_{2.5}$ in personal and ambient samples from two homes, two schools, and two offices located in the urban area of the city Agra. A total of 180 samples were collected from personal and ambient monitoring over 15 months from December 2013 to February 2015, i.e. 90 samples from personal monitoring and 90 samples from ambient monitoring. The monitoring was done for 24 hours for personal exposure and ambient sampling. For personal monitoring, the time period contains the occupant's daily indoor and outdoor activities. The number of samples gathered in a month duration was 12; six for the ambient environment (i.e. two from schools same way from homes and offices) and six samples of personal exposure (i.e. two from school and in similar fashion from homes and offices) respectively. Personal exposure measurements were carried out, using PEM (Personal Environmental Monitor, SKC Inc., USA) (**Figure 3**) with the Leland legacy sampling pump at 10 L/min, fitted within a waist pack to each individual participating. Rechargeable lithium-ion (Li-Ion) battery pack will provide 24-hour run time with impactors and other sampling devices with low back pressures. PEM is a lightweight, personal sampling device consisting of a single-stage impactor and an after-filter. Aerosol particles are sampled through the single-stage impactor to remove particles above the 50% cut-point of 2.5 μm in aerodynamic diameter. These large size particles are gathered on a greased ring and are rejected after sampling. Particles lesser than the 50% cut-point is authorized to pass through the impactor and get collected on a 37-mm after-filter paper. To investigate personal exposure, the filter is investigated gravimetrically for particle mass and chemical analysis. The sampling pump provides the required airflow through the PEM. The PEM operates on the principle of inertial separation of airborne particles using an impactor. Particle-laden air is accelerated into the sampler through the round nozzles located in a circle around the outer edge of the cover [9]. For $PM_{2.5}$ ambient samples were collected with a fine particulate dust sampler (APM 550, Envirotech) shown in **Figure 3**. The air inlet has a circular symmetrical hood designed to keep out of the rain, insects, and very large particles. The Inlet section leads to an Impactor stage, which traps particles larger than 10 microns aerodynamic diameter. The airstream

down in the tube carries particles. For the monitoring of PM$_{2.5}$, WINS Impactor is attached. It is designed to trap medium size particles between 2.5 and 10 microns. To avoid sampling fault due to bouncing of small size particulates from the impaction surface, a 37 mm diameter GF/A paper engrossed in silicon oil is used. The airstream now leaving the WINS Impactor consists of only fine particles with an aerodynamic diameter smaller than 2.5 microns. APM 550 uses an oil-less rotary pump to produce the suction pressure and critical flow control orifice (as recommended by [10]) for maintaining a constant airflow rate of 16.7 L/ min.

Filter papers were weighed thrice before and after sampling using five digits microbalance. Before weighing the samples were homogenized in desiccators at 20-30°C with a standard relative humidity range of 30–40% 24 hours. Filter cassettes were utilized to transport weighed filter papers to the sampling site, their filters were shifted to filter holders and positioned on the sampling plate. The exposed filter and the filter holder was then enfolded with aluminum foil, and were later placed back in the desiccators (**Figure 4**). Field blank filters were collected to lessen gravimetric prejudice due to filter handling after and during sampling duration. After evaluating, samples were refrigerated at 4°C to prevent the loss of volatile components as per the USEPA, Compendium Method, 1999. Exposed filter paper after conditioning and weighing was cut into two equal pieces. One part was used for acid extraction and the other half was preserved for later analysis. The other half of the exposed filter paper was put in pre-washed Borosil beakers such that the exposed paper faces toward the bottom of the beaker, then added 6–8 ml analytical grade (Merck) HNO$_3$ and HCl in the ratio 1:3 and kept on a hot plate at the temperature of 40-60°C for 90 minutes [11]. The beakers were covered with a watch glass filled with water to avoid the loss of volatile compounds due to evaporation. The solution was then filtered with prewashed Whatman filter paper. The

Figure 3.
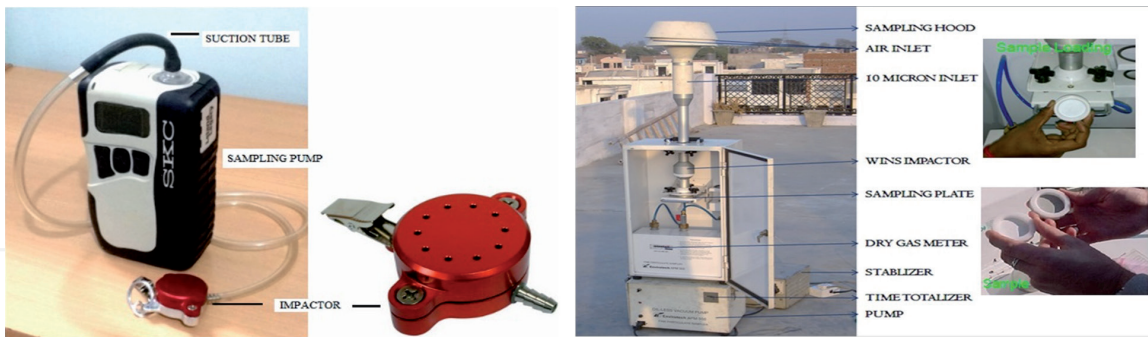*Personal environmental monitor (SKC Inc., USA) and fine particulate dust sampler (APM 550).*
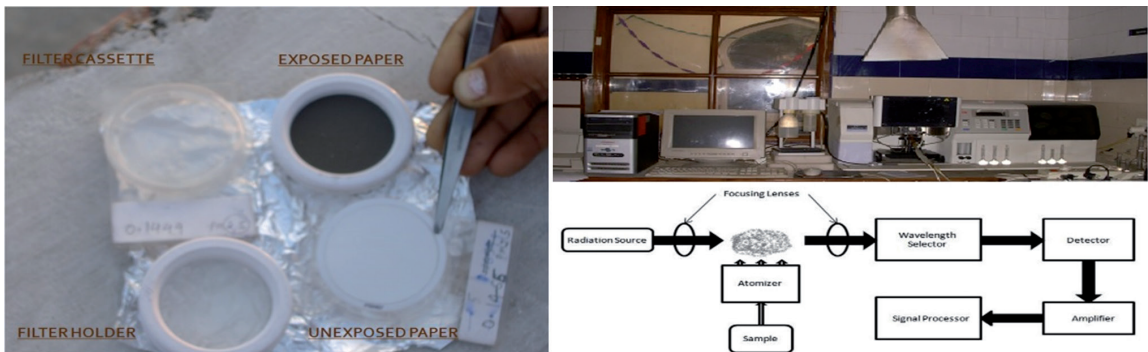

Figure 4.
Filter paper before and after sampling and atomic absorption spectrophotometer with schematic diagram (make: Perkin Elmer, AAnalyst 100).

wall of the beaker was washed 2–3 times with distilled water and allowed to stand for 30 min and then filtered without shaking. Finally, the extract was diluted up to 50 ml with distilled de-ionized water and stored in pre-washed polypropylene till analysis. Zinc (Zn), lead (Pb), nickel (Ni), iron (Fe), chromium (Cr), Cadmium (Cd) manganese (Mn), copper (Cu), Barium (Ba), and Mercury (Hg) were analyzed with this extract. Analysis of these trace metals was done on AAS regularly within two months of extraction.

5. Questionnaire survey

A Questionnaire survey is a common way to relate illness prevalence with air quality for small groups of individuals targeted for a specific purpose. It also gives us an idea about the potential sources of indoor air pollution, lifestyle, and different human activities (**Table 1**). A questionnaire (respondent schedule) was prepared from the personal interview of occupants from homes, schools, and offices, in all 475 were filled (i.e. 300 children and 275 adults) in different sampling locations, i.e. (homes, schools, and offices) of the Agra region. The questionnaire contains questions, which inquired about the personal exposure parameters and the occupant's perceptions of the air quality around them. The questionnaire includes daily time/ activity diary, age, sex, socio-demography, house/school/office characteristics, air exchange conditions, timing of different activities such as cooking in homes, cleaning, heating, number of occupants present near the source, other considerable characteristics. The information on the health-related issues of the occupants was also investigated like allergies, skin problems, cold and flu, vomiting or giddiness, eyes or nose annoyance, headache, and mental exhaustion. In the last part of the questionnaire survey, it was also investigated that the participants, if they were conscious of the harmful effects of polluted air? The results are discussed based upon the percentage of the data obtained below.

6. Health effects

Indoor air pollution is associated with a variety of health effects of both an immediate and long-term nature [12]. Short-term health effects may show up after single or repeated exposures (**Table 1**). They may include annoyance in the eyes, throat, and nose, headaches, cold, wooziness, and exhaustion. On the other hand, long-term health effects may appear or prevail after exposure has happened. These may comprise respiratory and heart diseases, and may also lead to cancer. As this study is of short term and limited to fifteen months, therefore only the short-term health-related issues are discussed as long-term exposure needs more years of study. According to the survey (**Table 1**), the most frequently occurring symptoms were headache (53% in the homes, 65% in the schools, and 52% in the offices), eyes, and nose irritation (53% in the homes, 60% in the schools and 48% in the offices), cold and flu (50% in the homes, 62% in the schools and 38% in the offices) allergies (35% in the homes, 45% in the schools and 20% in the offices) sinus, mental fatigue, nausea, and dizziness were at a somewhat lower percentage in the different microenvironments. The results show that these problems were more dominant in schools in comparison to homes and offices. The schools are also located near busy roads and streets of the city, vehicular emission causes the formation of fine particulate that penetrates indoors (higher values of r) and in turn is supposed to increase health-related problems [13, 14]. **Table 1** also shows a higher percentage of smoking with 42% was reported from homes than in comparison to offices whereas,

Parameters	Homes	Schools	Offices
Short-term health effects			
1. Headaches	53	65	52
2. Eyes and nose irritation	53	60	48
3. Cold and flu	50	62	38
4. Allergies	35	45	20
5. Sinus	20	22	14
6. Mental fatigue	28	35	22
7. Nausea and dizziness	18	20	13
Types of fuel used in homes			
1. L.P.G	95	NA	NA
2. Wood	3	NA	NA
3. Kerosene	2	NA	NA
4. Cow dung cakes	1	NA	NA
Cooking activities			
1. Refined oil	25	NA	NA
2. Mustard oil	70	NA	NA
3. Ghee	5	NA	NA
Other activities			
1. Candles or diyas	50	0	0
2. Incense sticks	75	0	60
3. Mosquito Coils	40	0	0
4. Smoking	42	0	35
5. Cleaning and Sweeping	Twice a day morning and evening	In evening after school hours	In evening after office hours
Ventilation inside the houses			
1. Ventilation acceptable	40	20	60
2. Ventilation not accepted	60	80	30
1. Aware	55	80	64
2. Not aware	45	20	36

Table 1.
Questionnaire survey analysis (in percentage).

the percentage reported from offices was also quite high with 35%. It was consistent with the results that health symptoms occurred more in indoor places where smoking was more common than in non-smoking [13, 15].

As the questionnaire data were collected from a different kind of socioeconomic status, family members living in different urban areas of the city, working in different places like offices, and their children studying in different schools. Their living stats are also different like the use of different kinds of fuels like wood, dung, and kerosene with the use of clean fuel like LPG (liquefied petroleum gas). As in the urban houses the per capita income increases, families generally shift to cleaner energy-efficient systems for their home energy needs. While particulate levels seem

to be closely associated with health effects, they normally seem in association with other contaminants. Thus, there is a need to distinguish different types of particles and how they can be best controlled [16].

7. PM2.5 results

The result obtained from the analysis, observation tables are drawn and presented below. $PM_{2.5}$ and its metal content in personal and ambient samples from homes, schools, and offices respectively during the sampling period from December 2013 to February 2015. During the study period, annual average concentration and standard deviations (SD) for PM2.5 (personal and ambient) at homes were 132.88 ± 43.28 μgm^{-3} and 122.78 ± 36.27 μgm^{-3}, at schools were 137.77 ± 42.18 μgm^{-3} and 127.19 ± 36.18 μgm^{-3} and at offices site 123.60 ± 41.44 μgm^{-3} and 109.20 ± 36.88 μgm^{-3} respectively. The concentration trend varied from 103.21 to 177.26 μgm^{-3} and 79.18 to 185.57 μgm^{-3} for personal and ambient concentrations at homes, at schools trend varied from 119.18 to 208.16 μgm^{-3} and 83.88 to 190.18 μgm^{-3} respectively. At offices $PM_{2.5}$ concentration varied from 93.05 to 161.78 μgm^{-3} and 78.16 to 181.15 μgm^{-3} respectively. This indicates that air quality in schools and homes is more affected by $PM_{2.5}$ and at offices have relatively better air quality. On comparing the annual average $PM_{2.5}$ concentration with National Ambient Air Quality Standard (40 μgm^{-3}) [17], It was found to be 3–4 times higher from personal and ambient concentration data collected from all the sampling places. We also compared our data with World Health Organization [18] standards (10 μgm^{-3} annual means respectively), our results exceeded 12.3–13.3 times at homes for personal and ambient monitoring and 12.8–13.8 times at schools and 10.9–12.4 times at offices.

High concentrations at the sampling sites may be attributed to heavy vehicular traffic flow, especially at schools, emissions from nearby industries and re-suspension of road and soil dust, emission from solid waste incineration, and construction activities. In homes and offices, cooking and smoking are the dominant activities, which should have contributed to the formation of fine particulate emissions. In the case of ambient, concentration levels were found to be elevated depending upon the outdoor activities.

On applying the one-way Anova to the mean values of particulate concentrations at all the sites for each location significance values $PM_{2.5}$ were adjacent to 1 or were around 1. For the homes, it ranged from 0.951 to 0.999, for the offices they ranged from 0.911 to 0.997 and for the schools it ranged from 0.917 to 0.997 signifying that there is no substantial variance between the concentrations of two offices, homes and schools and thus have similar kind of sources which lead to the generation of particulate pollutant in their environment. Due to the above reason, the discussion made in this report is explained based on the average concentration of two homes, two schools, and two offices located in each microenvironment rather than two houses, two schools, and two offices at different sampling sites.

8. Chemical constituent of PM2.5

Characterization of PM components, including inorganic elements, is of central importance in proposing mechanisms for health effects and in source apportionment studies [19, 20]. Data obtained by chemical analysis for ten metals in, $PM_{2.5}$ collected from personal and ambient environments at homes, schools, and offices.

The sum of the average concentration of ten parameters determined in $PM_{2.5}$ personal and ambient was found to be 19.09 μgm^{-3} and 12.12 μgm^{-3} at homes and

it ranged from 0.03–10.98 µgm^{-3} and 0.03–5.68 µgm^{-3} respectively. At schools, the sum of the average concentration was 21.48 µgm^{-3} and 12.93 µgm^{-3} and it ranged from 0.04–12.40 µgm^{-3}, 0.03–5.73 µgm^{-3} respectively; whereas at offices the sum of the average concentration was 16.93 µgm^{-3} and 11.05 µgm^{-3} and it ranged from

Parameters	PM$_{2.5}$ Personal (ugm^{-3})				PM$_{2.5}$ Ambient Environment(ugm^{-3})			
Homes	Mean	Sd	Max	Min	Mean	Sd	Max	Min
PM Conc.	132.88	43.28	177.26	103.21	122.78	36.27	185.57	79.28
Ba	10.98	4.33	16.78	4.67	5.68	1.93	7.89	4.05
Fe	2.63	1.99	7.21	0.63	1.33	1.56	4.11	0.12
Pb	1.12	1.12	3.55	0.06	1.12	0.67	2.17	0.17
Mn	0.06	0.07	0.25	0.02	0.22	0.28	0.49	0.13
Cu	0.40	0.35	1.07	0.04	0.36	0.55	1.10	0.03
Ni	0.60	0.58	1.85	0.03	0.68	0.85	2.95	0.05
Cr	2.39	1.35	6.09	0.30	0.60	1.03	3.06	0.03
Zn	0.53	0.51	1.89	0.03	1.75	2.26	3.33	0.26
Cd	0.35	0.09	0.38	0.18	0.35	0.12	0.37	0.23
Hg	0.03	0.01	0.04	0.02	0.03	0.01	0.03	0.01
Schools								
PM Conc.	137.77	42.18	208.16	119.18	127.19	36.18	190.18	83.88
Ba	12.40	4.85	17.73	5.20	5.73	2.00	7.95	4.66
Fe	2.70	2.09	7.38	0.80	1.51	1.74	4.22	0.14
Pb	1.15	1.19	3.62	0.12	1.37	0.86	2.43	0.20
Mn	0.09	0.08	0.32	0.03	0.23	0.28	0.50	0.16
Cu	0.45	0.32	1.08	0.04	0.39	0.53	1.16	0.05
Ni	0.72	0.60	2.02	0.06	0.70	0.84	3.29	0.08
Cr	2.99	1.70	6.27	0.36	0.71	1.20	3.12	0.06
Zn	0.58	0.57	1.96	0.04	1.84	2.21	3.48	0.24
Cd	0.36	0.10	0.42	0.20	0.42	0.13	0.38	0.23
Hg	0.04	0.02	0.04	0.02	0.03	0.01	0.04	0.01
Offices								
PM Conc.	123.6	41.44	161.78	93.05	109.20	36.88	181.15	78.16
Ba	9.45	4.85	15.12	4.35	4.86	1.92	7.65	4.06
Fe	2.39	1.73	5.74	0.43	1.36	1.55	4.07	0.09
Pb	1.02	1.09	3.51	0.05	1.12	0.53	2.09	0.13
Mn	0.04	0.06	0.23	0.01	0.20	0.29	0.44	0.08
Cu	0.35	0.33	1.03	0.02	0.34	0.43	1.05	0.04
Ni	0.57	0.64	1.62	0.02	0.63	0.68	2.83	0.03
Cr	2.37	1.45	5.77	0.31	0.55	0.78	2.88	0.03
Zn	0.42	0.45	1.67	0.01	1.68	2.07	3.28	0.20
Cd	0.30	0.10	0.31	0.26	0.30	0.06	0.30	0.21
Hg	0.02	0.01	0.03	0.01	0.01	0.01	0.02	0.01

Table 2.
Average metal concentrations (ugm^{-3}) in PM$_{2.5}$ by personal and ambient monitoring at homes, schools and offices.

0.02–15.76 μgm^{-3}, 0.01–4.86 μgm^{-3} in personal and ambient environment respectively. The total analyzed parameters contributed 13.69% to 14.36% and 9.87% to 10.16% for personal and ambient monitoring at homes, schools, and office sites. The unanalyzed part of the total $PM_{2.5}$ mass collected from personal and ambient monitoring may include carbon, organics, silicates, and phosphates [21, 22] (**Table 2**).

9. Multivariate analysis

Global emissions reported by many authors [23–28] have revealed as anthropogenic and natural sources can contribute to the principal aerosol classes, but values variate rendering to the local scenario (coarse, fine and ultrafine) of atmospheric particulate matter. Approximately 10–20% of the aerosols can be categorized as anthropogenic on an international scale [20, 29], but these values may drastically change due to local scenarios, human activities, and the prevailing particle cut-off. Correlation analysis is the statistical procedure applied for this assessment. The levels of various elements in $PM_{2.5}$ vary by diverse orders of scale and hence the correlation analysis was utilized. Correlation analysis was done to study the connection between ambient and personal sources among metallic species. **Table 3** shows the interrelation between metallic species at the schools, homes, and offices, during the sampling period. The samples used for the analysis were (n = 90) and the eight variables in each sample of $PM_{2.5}$. Fe presented the maximum concentration in indoor homes, schools, and offices followed by Cr, Pd, Zn, Ni, Cu, Cd, Mn, Ba, and Hg. The coefficient of variance was in the order of Fe > Ni > Zn > Cr > Mn > Cu > Ba >Cd > Pd > Hg. Comparable kinds of trends are found in trace metal concentrations in all three types of sites, indicating that there could be one or additional similar kinds of sources contributing to a somewhat similar kind of urban environment of the city area. Correlation analysis was done to achieve the association between individual trace metals and to show that two or more components may associate either due to common cause (**Table 3**) Zn and Ni showed good to strong correlation with Cr (R^2 = 0.712 and 0.824) and Mn (R^2 = 0.758 and 0.792) at homes sites, (R^2 = 0.876 and 0.996) and (R^2 = 0.502 and 0.687) at school sites and (R^2 = 0.798 and 0.975) and (R^2 = 0.821 and 0.946) at office sites. These correlations indicate smoking done by the occupants in the indoor working environment and incense burning could be the probable source of these trace metals [30]. Fe too showed strong correlation with Cu at these three sites (R^2 = 0.913, 0.921 and 0.902), followed by Cr with Mn (R^2 = 0.736, 0.826 and 0.872) and Ni with Cr (R^2 = 0.824, 0.501 and 0.821). Anthropogenic activities and the use of different mechanical and electrical apparatus like computers, printers, and photocopiers, etc. The work environment can give rise to emissions of such metals [29, 31]. Ni also showed a correlation with Cd (R^2 = 0.512 and 0.501) at homes and school sites which may be due to ambient sources. Ba showed a strong correlation with Fe and Cu (R^2 = 0.645 and 0.503) at home sites, (R^2 = 0.678 and 0.512) at school sites and, (R^2 = 0.719 and 0.567) at office sites, indicating outdoor sources like vehicles brake lining and other anthropogenic can contribute to it [32]. Whereas; Hg showed no significant correlation with any of the other metal species at any of the sampling sites.

10. Conclusion

Through this research work, we have been able to identify that personal exposure monitoring is a practical technique for improving knowledge about

Home	Zn	Pd	Ni	Fe	Cr	Cd	Mn	Cu	Ba	Hg
Zn	1.000									
Pd	0.455	1.000								
Ni	0.687*	0.264	1.000							
Fe	0.211	0.421	0.475	1.000						
Cr	0.712*	0.487	0.824*	0.664*	1.000					
Cd	0.216	0.124	0.512*	0.227	0.427	1.000				
Mn	0.758*	0.348	0.792*	0.216	0.736*	0.178	1.000			
Cu	0.372	0.367	0.218	0.913*	0.689*	0.246	0.215	1.000		
Ba	0.116	0.123	0.216	0.645*	0.056	0.187	0.114	0.503*	1.000	
Hg	0.009	0.050	0.079	0.010	0.098	0.102	0.008	0.009	0.004	1.000
School										
Zn	1.000									
Pd	0.368	1.000								
Ni	0.497	0.168	1.000							
Fe	0.318	0.336	0.587*	1.000						
Cr	0.876*	0.421	0.501*	0.478	1.000					
Cd	0.325	0.248	0.501*	0.246	0.416	1.000				
Mn	0.996**	0.485	0.226	0.364	0.826*	0.325	1.000			
Cu	0.116	0.167	0.697*	0.921**	0.348	0.348	0.139	1.000		
Ba	0.120	0.131	0.203	0.678*	0.045	0.201	0.128	0.512*	1.000	
Hg	0.010	0.061	0.062	0.012	0.078	0.117	0.009	0.006	0.005	1.000

Home										
	Zn	**Pd**	**Ni**	**Fe**	**Cr**	**Cd**	**Mn**	**Cu**	**Ba**	**Hg**
Office										
Zn	1.000									
Pd	0.358	1.000								
Ni	0.826*	0.276	1.000							
Fe	0.296	0.331	0.379	1.000						
Cr	0.798*	0.167	0.821*	0.334	1.000					
Cd	0.058	0.256	0.428	0.387	0.342	1.000				
Mn	0.975**	0.428	0.946**	0.421	0.872*	0.315	1.000			
Cu	0.018	0.348	0.167	0.902*	0.216	0.246	0.216	1.000		
Ba	0.118	0.136	0.198	0.719*	0.044	0.201	0.103	0.567*	1.000	
Hg	0.007	0.072	0.045	0.0013	0.045	0.110	0.010	0.005	0.008	1.000

*Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 3.
Correlation matrix at home, school and office sites.

individual-level exposure to environmental stressors. This exploration work summaries the elemental characterization, correlation analysis, and health risks concomitant with fine particle PM$_{2.5}$ that is generated during different activities at homes, schools, and offices.

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