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ARTICLE

Indoor Air Pollution and Its Determinants in Household Settings in Jaipur, India

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ABSTRACT

Individuals spend 90% of their time indoors, primarily at home or at work. Indoor environmental factors have a significant impact on human well-being. It was a longitudinal study that assessed the major factors that reduce indoor air quality, namely particulate matter, and bio-aerosols, using low-cost sensors and the settle plate method, respectively also to determine the effect of atmospheric parameters and land use patterns in households of commercial, industrial, residential, slum, and rural areas of the city. PM2.5 concentration levels were similar in most parts of the day across all sites. PM10.0 concentration levels increased indoors in a commercial area. PM2.5 concentration showed a negative correlation with temperature and a positive correlation with relative humidity in some areas. Very high values of PM2.5 concentration and PM10.0 concentration have been observed in this study, inside households of selected rural and urban areas. Pathogenic gram-positive cocci, gram-positive rods, Aspergillus, and Mucor species were the most common bacterial and fungal species respectively found inside households. This study examined particulate matter concentration along with bio-aerosols, as very less studies have been conducted in Jaipur the capital of Rajasthan, a state in the western part of India which assessed both of these factors together to determine the indoor air quality. Rural households surrounding the periphery of the city were found to have similar pollution levels as urban households. So, this study may form the basis for reducing pollution inside households and also for taking suitable measures for the reduction of pollution in the indoor environment.

Keywords: Indoor air pollution; Particulate matter; Bio-aerosols

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1. Introduction

There is regional heterogeneity in India, where places with various atmospheric conditions result in different indoor air quality. North Indian states, for example, have higher PM2.5 g/m^3 levels (557-601 g/m^3) than southern states (183-214 g/m^3) [1]. Because of their low incomes, those who utilize solid biomass for domestic purposes are exposed to poor-quality, toxic air within their homes. It is noteworthy that three billion people use the aforementioned energy source to prepare their everyday needs for cooking and heating [2]. Long-term exposure to indoor environments with insufficient air exchange and poor air quality and harmful bio-aerosols may cause sick-building syndrome (SBS), allergic reactions, respiratory tract infections, chronic obstructive pulmonary disease(COPD), and asthma [3]. Since most individuals spend 90% of their time indoors, primarily at home or at work, indoor environmental factors have a significant impact on human well-being [4]. Indoor air pollution can be produced by occupant activities such as cooking, smoking, using electronic equipment, using consumer products, or emissions from building materials inside homes or structures. Dangerous pollutants can be found inside buildings, including biological contaminants, particulate matter (PM), aerosols, volatile organic compounds (VOCs), carbon monoxide (CO), and others [5]. Biological aerosols (bio-aerosols) are a subgroup of atmospheric PMs made up of cellular components, microorganisms (bacteria and archaea), and dispersal units (fungal spores and plant pollen) [6]. Indoor air pollution levels can be impacted by concentrations of outdoor air pollution associated with anthropogenic and natural sources, including road traffic, wildfire smoke, and dust re-suspension. Additionally, factors including the kind, location, and distance of the pollutant sources; the size, shape, orientation, and arrangement of the buildings; as well as geography and weather patterns, all have an impact on how the pollutants around the structure disperse [7]. Indoor exposure is greatly influenced by household characteristics and occupant behaviours, particularly cigarette smoking for PM2.5, gas appliances for NO_2, and household items for volatile organic compounds (VOCs) and polyaromatic hydrocarbons (PAHs). High interior air pollution is caused by a home's proximity to busy highways, redecorating, and tiny housing size [8]. People in metropolitan areas spend more than 90% of their waking hours indoors, according to research on this group. A considerable majority of people's time is spent outside of residential indoor spaces, in workplaces, schools, and other commercial and industrial structures. Adults in North America spend 87% of their time indoors, with the remaining 17% spent in automobiles and 7% outdoors, according to specific studies [9]. Studies have indicated that breathing "clean" indoor air helps with both respiratory and non-respiratory symptoms like headaches and eye pain [10]. A common but avoidable risk factor for respiratory illnesses is household air pollution. The most efficient intervention to lower the burden of household air pollution (HAP)-related diseases is probably the substitution of solid cooking fuels with clean fuels like liquid petroleum gas (LPG), as demonstrated by India's "Ujjwala" initiative [11]. In India, the national burden of disease is accounted for by environmental and occupational risk factors, with indoor and outdoor air pollution ranked as one of the major risk factors [12].

Very little data are available on indoor air pollution in Jaipur. Therefore, the study was carried out with the objectives of studying indoor air pollution in different household settings in Jaipur and determining the effect of atmospheric parameters and land use patterns.

2. Materials and methods

Study location: The study was conducted in Jaipur, the capital of Rajasthan, a state in the western part of India. The Thar Desert is a part of the state. It is located at latitude-N 26.922070 and longitude-E 75.778885. It has a population of 3,073,350 (2011 Census) and is spread over 11,143 km^2. The city has mixed land use, with residential, commercial, and industrial areas coexisting and dotted with slum clusters in between. At its periphery, the city is surrounded by rural areas where the primary occupation is farming.

Study Design: Longitudinal Study Design.

Study location: For data collection, one household was chosen from each of the following areas: residential, commercial, industrial, slum, and rural (**Figure 1**).

Data collection: Data on pollution parameters were collected in selected households through real-time continuous monitoring of particulate matter using laser base sensors and outdoor data were obtained from Rajasthan State Pollution Control Board (RSPCB). Assessment of bio-aerosols in the households to identify pathogenic microorganisms present inside households was done using the passive settle plate method.

Indoor air quality was monitored using sensor-based low-cost air quality monitors, the Purple Air PA-II (Manufactured by Purple Air Inc., USA). One unit was installed in each of the selected households. Data were collected for a period of three months from 07 March 2022 to 30 June 2022. The device captured PM2.5 levels at a 60-second interval along with PM10, PM1.0, temperature, and relative humidity.

On the day of sampling, the Petri plates were examined for contamination prior to use for the bio-aerosol assessment. The labeling of information and media pouring was done in a laminar air flow hood in a sterile environment. The plates were covered with a sterile lid and were assembled in a sterile transport bag or container according to the schedule of sampling. At the sampling site, the passive settle plate method was used, which meant that the Petri dish was placed 1 m above ground level, 1 m from any obstacle, and exposed for one hour. The exposed Petri dishes for bacteria were incubated at 37 degrees Celsius, for 48 hours of growth and CFU/plate was counted. Petri dishes for fungi were incubated at 28 degrees Celsius, for 72 hours of growth and CFU/plate was counted. Bacterial colonies grown on blood agar were subjected further to gram staining for identification of gram-positive and gram-negative bacteria. Fungal colonies were subjected to staining with cotton blue dye for identification of the type of fungi species.

Data analysis: The PM2.5 $\mu g/m^3$ levels obtained from the monitors were transferred to an MS Excel sheet and converted into six hourly average values.

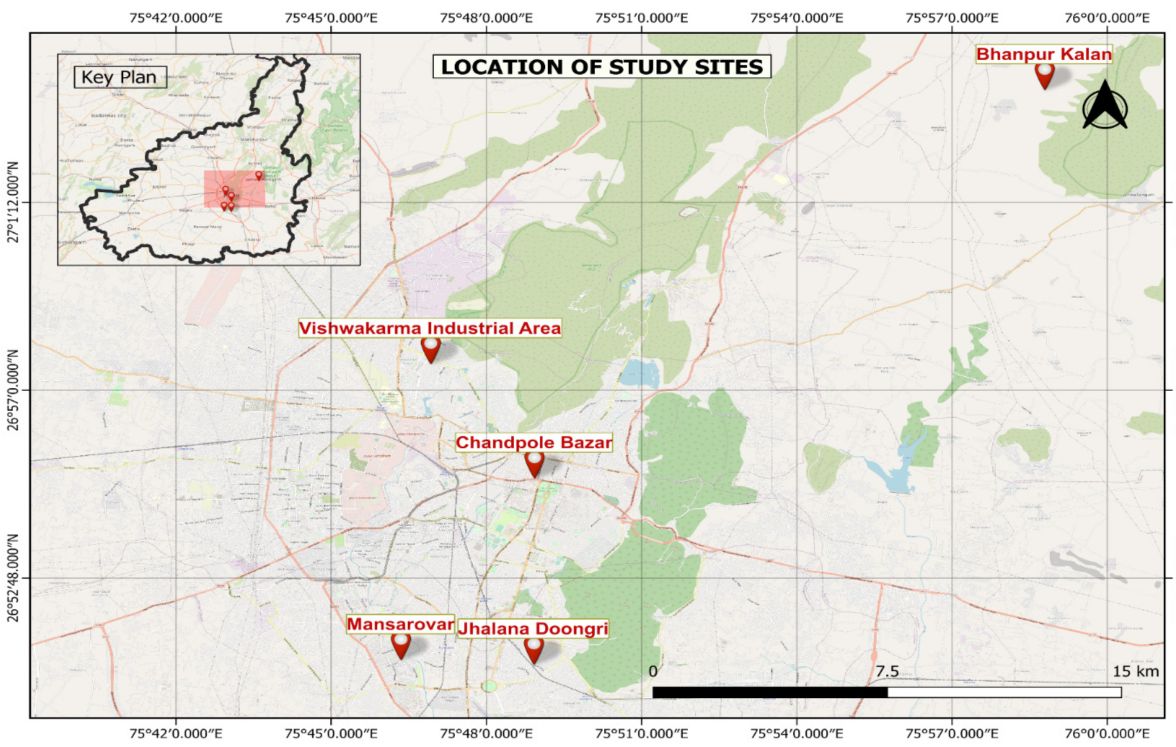

Figure 1. Sampling sites map of Jaipur, Rajasthan, India.

The quarters were divided as 6.00 a.m. to 11.59 a.m., 12.00 noon to 5.59 p.m., 6.00 p.m. to 11.59 p.m., and 0.00 hours to 5.59 a.m. Similarly, the temperature and relative humidity data were also converted to six-hourly averages.

3. Results

The quarterly average values of PM2.5 μg/m^3 of all sites for three months are shown in graphs (**Figures 2 to 5**). It was found that in the morning hours, PM2.5 μg/m^3 values in all places were highest in March than in April; this might be due to low ambient temperature and high humidity observed during this time, as shown in **Figure 2**. In the afternoon slot, as shown in **Figure 3**, all the places have shown different rise and drop patterns, indicating other factors like domestic pollutant emission sources and external outdoor sources affect PM2.5 μg/m^3 concentration and values. The evening and night slot values of PM2.5 μg/m^3 also varied spatially. Very high concentrations of particulate matter are found inside households as the moderate range for PM2.5 is from 0 to 35 and for PM10.0 it is 51-154 according to air quality index: a guide to air quality and your health. EPA, August 2019 AQI air quality index "a" People with heart or lung disease, children, or older adults (EPA-456/F-19-002), as in most areas the values are reaching 250 to 300 which is above the normal range.

3.1 Indoor and outdoor PM10.0 μg/m^3 levels

A comparison of PM10.0 μg/m^3 twenty-four hourly average data obtained from Purple Air PA-II (Manufactured by Purple Air Inc., USA) with outdoor PM10.0 μg/m^3 twenty-four hourly average data obtained from Rajasthan State Pollution Control Board (RSPCB) from March 2022 to May 2022 is given in **Figures 6 to 9**. On March 22nd, we observed that the value of PM10.0 μg/m^3 increased indoors (101 μg/m^3) as compared to outdoors (74 μg/m^3) in the commercial area due to heavy dust presence by the construction work taking place in the street during this time period which also affected the households nearby. Again, on April 8th, 2022, the value of PM10.0 μg/m^3 increased in the commercial area.

3.2 Correlation of PM2.5 μg/m^3 and temperature

PM2.5 μg/m^3 and temperature were found to have a negative correlation at the 0.01 (2-tailed) level in industrial (–0.445), rural (–0.447), slum (0.358), residential (–0.315) areas and not in a commercial area.

3.3 Correlation of PM2.5 μg/m^3 and relative humidity

A positive correlation between PM2.5 μg/m^3 and humidity was found to be significant at the 0.01 level (2-tailed) in commercial areas (0.161), rural areas (0.557), slum areas (0.257) and not in an industrial and residential area as there were no proper ventilation sources present in commercial, rural and slum area so, due to humid environment particulate matter showed a positive correlation with humidity whereas residential area has proper ventilation sources and industrial area have more of the dusty environment due to continuous industrial activities, factories work and on road traffic presence so a negative correlation was observed.

3.4 The effect of land on bacterial and fungal counts

In the rural area, the bacterial microbial counts were highest inside the bedroom, bathroom, kitchen, and living room as compared to other areas as shown in **Table 1**, due to the presence of more dust, pet presence, improper cleaning of households, access to pet waste, no ventilation sources like exhaust fans or air purifiers, biomass fuel used for cooking which produced more waste and improper waste disposal as compared to urban and slum area where these reasons were less observed. Also, the fungal microbial counts in the bathroom, bedroom, kitchen, and living room were more due to similar reasons as compared to other areas as shown in **Table 2**. Pathogenic gram-positive cocci and gram-positive rods were the dominant bacterial species found in all the areas. Aspergillus and Mucor species were identified as the dominant fungal species in all the sampled households in the city which can cause a group of infections.

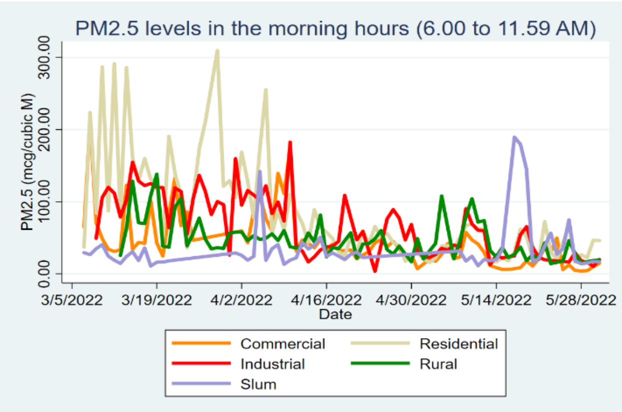

Figure 2. All five zones' quarter 1 PM2.5 μg/m³ values.

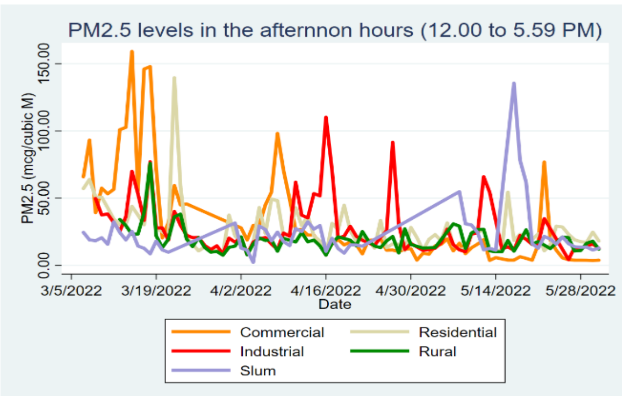

Figure 3. All five zones' quarter 2 PM2.5 μg/m³ values.

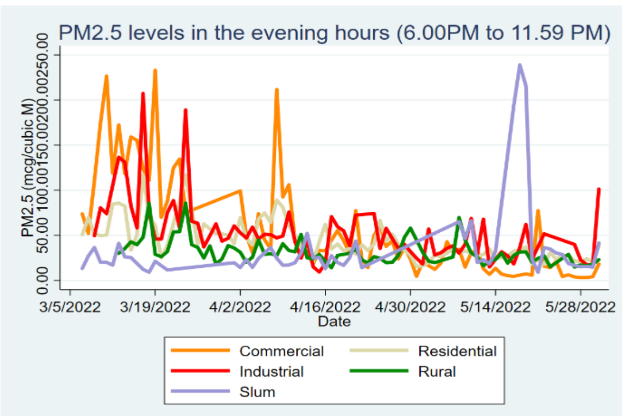

Figure 4. All five zones' quarter 3 PM2.5 μg/m³ values.

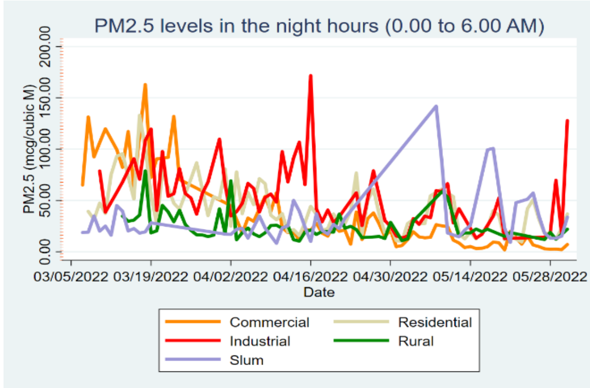

Figure 5. All five zones' quarter 4 PM2.5 μg/m³ values.

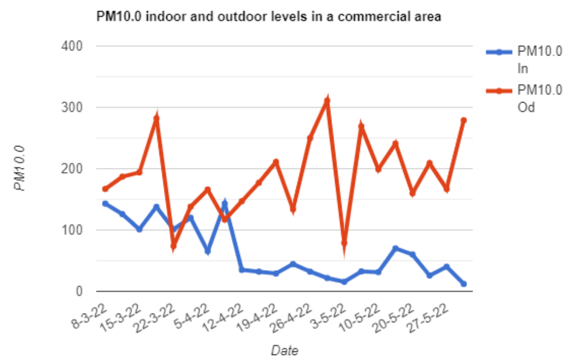

Figure 6. PM10.0 μg/m³ indoor and outdoor levels in a commercial area.

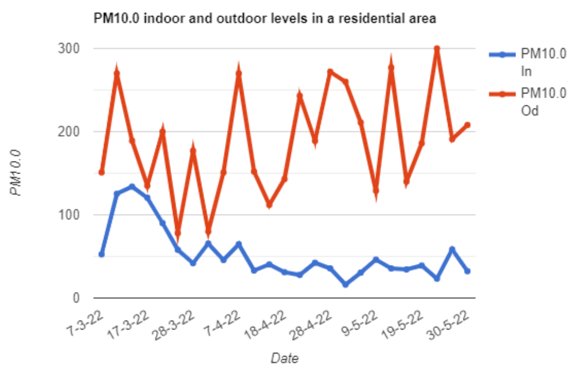

Figure 7. PM10.0 μg/m³ indoor and outdoor levels in a residential area.

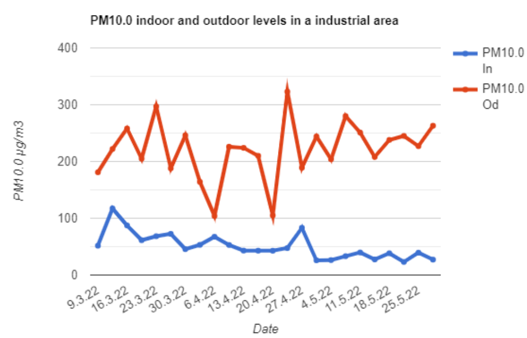

Figure 8. PM10.0 μg/m³ indoor and outdoor levels in an industrial area.

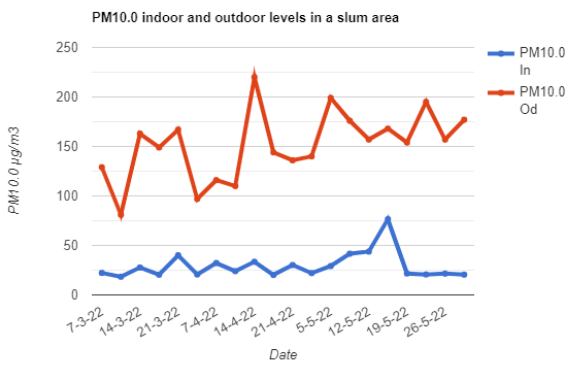

Figure 9. PM10.0 µg/m^3 indoor and outdoor levels in a slum area.

4. Discussion

The patterns of PM2.5 µg/m^3 levels were similar for three-quarters of the day across all sites. PM2.5 µg/m^3 showed a statistically significant negative correlation with temperature and a positive correlation with relative humidity in some areas of the city. Very high values of PM2.5 µg/m^3 and PM10.0 µg/m^3 have been observed in the study inside households including rural areas. The effect land used on microbial counts (bacterial and fungal) is shown. Inclusion of all the environmental (presence of different PM levels, presence of different bio-aerosols with their amounts), geographical (all the different land patterns taken for the study), and atmospheric parameters (temperature and relative humidity) in Jaipur city and based on the observed results, it can be safely inferred that indoor air pollution is as high as outdoor air pollution, contrary to the belief about indoors being less polluted. In the case of extreme pollution, residents are advised to stay indoors. It was also an important observation, that rural households were as polluted indoors as urban households.

5. Conclusions

This study examined particulate matter concentration and bio-aerosols in households in Jaipur. Rural households have similar pollution levels as urban areas. Many policies have been introduced to reduce the level of outdoor air pollution but very less policies have been introduced which are working on indoor air pollution and their implementation remains a challenge. Issues with air quality starts at home,

Table 1. The influence of land used on bacterial microbial counts (CFU/Plate).

Place -	Commercial area	Industrial area	Slum area	Residential area	Rural area
Bedroom	25	45	18	20	95
Kitchen	22	16	19	9	33
Barth room	50	23	12	8	88
Living room	25	24	21	14	39
Balcony	50	47	30	40	30

Table 2. The influence of land used on fungal microbial counts (CFU/Plate).

Place-	Commercial area	Industrial Area	Slum area	Residential area	Rural area
Bedroom	4	5	1	2	6
Kitchen	8	2	3	3	6
Barth room	1	2	4	2	7
Living room	6	7	6	3	7
Balcony	4	6	3	5	9

switching to renewable energy sources, providing sufficient ventilation in dwellings, and cross ventilation in homes can also assist, using exhaust fans in homes with inadequate ventilation helps re-mediate the air quality issues. Rural areas should switch to LPG for cooking purposes, as biomass fuel usage along with regular smoking is affecting health at a crucial level, maintenance of hygiene in the house by cleaning animal droppings regularly should come into practice. This study may form the basis for reducing pollution in households.

Ethical Approval

The proposal was approved by the Institutional Ethics Committee of ICMR-NIIRNCD, Biomedical and Health Research ICMR-NIIRNCD Jodhpur.

Author Contributions

1) Corresponding Author - Anukrati Dhabhai, (Project technical officer) ICMR – NIIRNCD, single handedly collected data from all locations in Jaipur city, performed all the laboratory tests and identifications of bioaerosolsand prepared proposal, manuscript, and did the data analysis.

2) Co-author - Dr. Arun Kumar Sharma, Director, (Scientist "G") ICMR – NIIRNCD, Jodhpur helped in conceptualizing the proposal, data analysis and manuscript preparation.

3) Co-author - Dr Gaurav Dalela, Head of Department (Microbiology) RUHS, College of Medical Sciences helped in bio-aerosols estimation and identification.

4) Co-author - Dr S.S Mohanty, (Scientist "E") ICMR-NIIRNCD helped in bio-aerosols estimation with fungal identification.

5) Co-author - Dr Ramesh Kumar Huda, (Scientist "C") ICMR-NIIRNCD provided help and support in execution of laboratory work for bioaerosols estimation.

6) Co-author - Dr Rajnish Gupta (Technical Assistant) ICMR-NIIRNCD helped in all ways possible to carry out bio-aerosols part of the study along with fungal identification.

Conflict of Interest

The authors share no conflict of interest.

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