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Assessment of Indoor Air Quality and Influential Factors: A Study in Rural Areas of Solan District, Himachal Pradesh (India)

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ABSTRACT

The study was conducted during December, 2020 to June, 2021 to assess indoor air quality (IAQ) and develop amelioration strategies in rural areas of the Solan district, located in Himachal Pradesh, India. A well-structured pre-tested questionnaire was used to assess the factors responsible for indoor air quality.The indoor air quality parameters including PM_{10}, Non-Respirable Suspended Particulate Matter (NRSPM), Total Suspended Particulate Matter (TSPM), Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2)were studied to calculate air quality index.The findings revealed substantial variation in pollution levels among different villages. Nauni village had the highest concentration of pollutants, with PM_{10} levels at 24.17 µg m^{3-1}, NRSPM at 20.37 µg m^{3-1}, TSPM at 44.54 µg m^{3-1}, NO_2 at 12.54 µg m^{3-1} and SO_2 at 0.35 µg m^{3-1}. In contrast, Nagali village has the lowest levels of these contaminants. Despite variations, all recorded values were within permissible limits. Nine factors were identified as contributing to poor indoor air quality: fuel wood-based cooking, smoke sources, mode of ventilation, insect/pest control measures, waste disposal near the house, use of perfumes and air freshners, cowshed near the house, intermittent cleaning, and dampness in the house due to leakage. To reduce indoor air pollution in rural areas, the study suggests establishing concentrated methods that address these specific issues. Proper ventilation, alternate cooking methods and better waste management procedures are important steps in improving indoor air quality and protecting public health.

KEYWORDS: Air, quality, indoor, pollutant, mitigation, ventilation

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1. INTRODUCTION

Animals, plants, soil, water, and other living and non-living components are all part of the environment and have an impact on our everyday existence. Among them, air is one of the most important constituents of the atmosphere, and its quality is critical to preserving the delicate balance of life on earth. Air quality refers to the state of the air in a certain location; excellent air quality is clean, clear and devoid of pollutants including smoke, dust, industrial or domestic pollution, and other gaseous impurities. Humans, plants, animals, non-living things and natural resources all require clean air to function properly. Poor air quality, on the other hand, endangers human health and environmental stability (Kampa and Castanas, 2008).

Air pollution, produced by a variety of contaminants, has emerged as one of the most serious environmental challenges (Burnett et al., 2018). A significant fraction of the global population is exposed to harmful levels of air pollution, with more than 3.5 billion people living in areas with poor air quality. In India, 75% of the population is exposed to air pollution levels that exceed permissible standards (Smith, 1993). This exposure encompasses all micro-environments where people spend their time (Lawrence and Taneja, 2005). Urbanization and industrialization have exacerbated air-quality issues in cities across the world, with motor traffic cited as a major source of pollution (Mage et al., 1996). The release of dangerous substances into the environment as a result of numerous natural and anthropogenic activities adds to the degradation of air quality, which harms human health and ecosystems (Balakrishnan et al., 2011).

Indoor air pollution (IAP), a substantial component of total air pollution is the chemical, biological and physical contamination of indoor air (Chafe et al., 2014). In underdeveloped nations, IAP is seen as one of the most important environmental health concerns. The World Health Organization (WHO) rates indoor air pollution as the ninth most significant risk factor contributing to the global illness burden. IAP can have a greater negative impact than ambient air pollution, especially in rural regions where traditional fuels such as firewood, charcoal, and cow dung are utilized for cooking and heating (Kankaria et al., 2014). Poor ventilation in dwellings increases the concentration of indoor pollutants, resulting in serious health repercussions.

Himachal Pradesh, a mountainous state in India, with over 80% of its people living in rural regions, where traditional cooking techniques and a lack of knowledge about indoor pollution contribute to high rates of respiratory illness (Saiyed et al., 2001). The district of Solan, where 82.4% of the population lives in rural regions, is an excellent illustration of this problem. Despite the importance of indoor air pollution, research and monitoring efforts in India have mostly concentrated on urban environments, with significant gaps in rural areas (Karambelas et al., 2018). Long-term studies and planned interventions are urgently needed to solve rural India's particular difficulties with indoor air pollution.

To address this critical issue, the current study named " Assessment of Indoor Air Quality and Influential Factors: A Study in Rural Areas of Solan District, Himachal Pradesh (India)" was conducted. The study's goal is to provide data that will be useful to researchers, academics, health organizations, environmental institutions, pollution control boards, non-governmental organizations (NGOs), and policymakers. By concentrating on the rural population of Solan district, this study aims to emphasize the crucial need for focused interventions to reduce the health risks caused by indoor air pollution in rural India. The objectives of the study were to assess the indoor air quality of rural households and to document the factors responsible for indoor air quality.

2. MATERIALS AND METHODS

2.1. Study area and site selection

The study was carried out during December 2020 to June 2021.The six households selected randomly from each village falling under four panchayats viz. Nauni, Samror, Serbanera and Oachghat in the district of Solan (Table 1) with 30°44' to 31°22' N latitude and 76°36' to 77°15' E longitude with 1300m amsl (Figure. 1). Climate of the study area varies from sub- tropical to temperate, with average annual temperature of 25.1°C. The average rainfall in the district was 1262 mm with 90% received during the south west monsoon season.

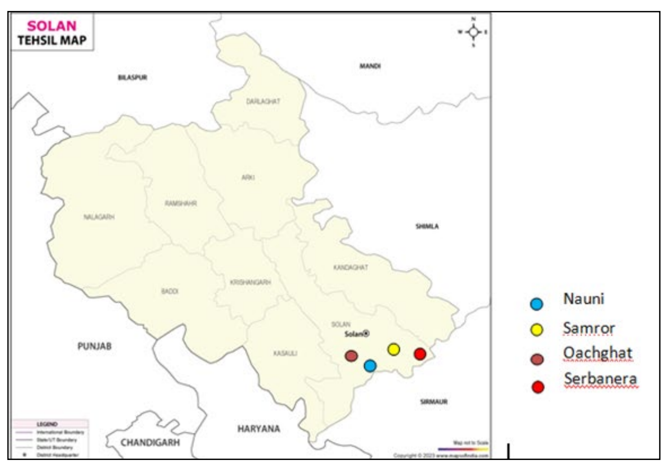

Figure 1: Study area

2.2. Data collection

The data on indoor air pollution was recorded by putting Fine Dust Sampler (DFPM 2.5 SAMPLER) for eight hours 8 AM to 16 PM in each house during day time for one

Table 1: Number of households selected from four villages of each Panchayat

Sr. No.	Name of Panchayat	Name of the villages	No. of households
1.	Nauni	Nauni	6
2.	Samror	Samror	6
3.	Serbanera	Serbanera	6
4.	Oachghat	Oachghat	6

day from one house and continued in other houses in the consecutive days. The air pollutants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), PM_{10} (Particulate Matter), Non-Respirable Suspended Particulate Matter (NRSPM) and Total Suspended Particulate Matter (TSPM) were recorded. In order to assess the factors responsible for indoor air quality, a well-structured pre-tested questionnaire was used to collect the data through personal interviews of the households.

2.3. Data analysis

2.3.1. Estimation of air quality index (AQI)

The quality of air in the study area had been estimated from the air quality index. The air quality index had been calculated from the observed SPM, PM_{10}, NO_2 and SO_2 values using the formula. $AQI=1/4\times(I_{PM10}/S_{PM10}+I_{SPM}/S_{SPM} + I_{SO2}/S_{SO2}+I_{NOx}/S_{NOx})\times100$

The obtained data was compared with permissible limits of different air pollutants for national ambient air quality standards (Table 2) and also with standards of AQI (Table 3).

Table 2: Permissible limits of different air pollutants for national ambient air quality standards (CPCB)

Sl. No.	Pollutant	Time Weighted Average	Standards: Concentration in ambient air		Methods of measurement
			Industrial area residential, rural and other areas	Ecologically sensitive area (Notified by Central Govt.)	
1.	Sulphur Dioxide (SO_2)	Annual Avg* 24 hours**	50 µg m^{3-1} 80.0 µg m^{3-1}	20.0 µg m^{3-1} 80.0 µg m^{3-1}	-Improved West and Gaeke method -Ultraviolet fluorescence
2.	Oxides of Nitrogen as NO_2	Annual Avg* 24 hours**	40.0 µg m^{3-1} 80.0 µg m^{3-1}	30,0 µg m^{3-1} 80.0 µg m^{3-1}	-Modified Jacob and Hochheise (Sodium Arsenite) -Chemiluminescence
3.	Particulate matter (size less than 10 µm)	Annual Avg* 24 hours**	60.0 µg m^{3-1} 100.0 µg m^{3-1}	60.0 µg m^{3-1} 100.0 µg m^{3-1}	-Gravimetric -TOEM -Beta attenuation
4.	Particulate matter (size less than 2.5 µm)	Annual Avg* 24 hours	40.0 µg m^{3-1} 60.0 µg m^{3-1}	40.0 µg m^{3-1} 60.0 µg m^{3-1}	-Gravimetric -TOEM -Beta attenuation

• Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval,
• ** 24 hourly/ 8 hourly or 1 hourly monitored values as applicable shall be complied with 98% of the time in a year. However, 2% of the time, they may exceed the limits but not on two consecutive days of monitoring

Table 3: Air quality index (AQI) standards

AQI value	Remarks	Health Concern
0–50	Good	None/minimal health effect
51–100	Moderate	Few or none for the general population
101–150	Unhealthy for sensitive groups	Possible respiratory or cardiac effect for most sensitive group
151–200	Unhealthy	Increasing symptoms of respiratory illness
201–300	Very unhealthy	Aggravation of heart and lung disease
301–500	Hazardous	Serious aggravation. Risk of death in children

3. RESULTS AND DISCUSSION

3.1 Parameters of indoor air quality

3.1.1. Particulate matter (PM_{10})

The data revealed that there was a significant variation in concentration of PM_{10} in indoor air at different villages of Solan district (Table 4). The concentration of PM_{10} varied from 16.63 to 24.17µg m^{3-1} and found within the permissible limits as prescribed by CPCB (Table 3). Nauni had the highest PM_{10} concentration (24.17 µg m^{3-1}) followed by Samror (23.73 µg m^{3-1}), Serbanera (20.42 µg m^{3-1}) and Nagali village had the lowest (16.63 µg m^{3-1}). However, the concentrations of PM_{10} at Nauni and Samror found at par.

The highest concentration of PM_{10} was found in Nauni village due to poor ventilation in buildings (fewer windows and no exhaust fan), higher vehicular frequency and continuing developmental activities. Nagali had the lowest concentration of PM_{10} due to good ventilation used by the households and a clean surrounding environment due to the existence of abundant vegetation and no traffic pollution because it was located far away from the state highway and other local roads. PM_{10} concentrations were greater in Samror and Serbanera villages than in Nagali due to poor ventilation, traffic pollution and construction activities in which building materials were kept on the roadside in open circumstances. The poor indoor air quality was not only related with enclosed rooms, but it could also be caused by problems in the ventilation system or design, which might bring pollutants from outside into inside regionsby Junaid et al. (2009).

3.2. Non-respirable suspended particulate matter (NRSPM)

There was a significant variation in the concentration of NRSPM among the selected villages. The NRSPM concentration varied from 12.92–20.37 µg m^{3-1} which was far behind the permissible limits as given by CPCB (Table 2). Nauni village had the highest concentration of NRSPM (20.37 µg m^{3-1}), followed by Samror, Serbanera and Nagali village with the concentrations of 18.83, 16.54 and 12.92 µg m^{3-1}, respectively (Table 4).

Table 4: Concentration of indoor air pollutants (µg m^{3-1}) at different rural households

Villages	PM10	NRSPM	TSPM	NO_2	SO_2
Nauni	24.17	20.37	44.54	12.54	0.35
Samror	23.73	18.83	42.56	10.01	0.33
Serbanera	20.42	16.54	36.96	9.99	0.32
Nagali	16.63	12.92	29.55	8.28	0.30
Mean	21.23	17.16	38.40	10.20	0.32
CD (*p*=0.05	2.88	3.03	4.69	2.35	0.02

The highest NRSPM concentrations in Nauni village might be attributed to combustion-related sources such as fuelwood-based cooking, smoking and incense/dhoop burning within the house also due to inadequate ventilation and increased vehicle usage. The Nagali location had the lowest NRSPM concentration due to the presence of adequate vegetation and efficient home ventilation, which aided in the discharge of particulate matter from inside to the environment. Stabile et al. (2012) also reported that dhoop, incense and burning activities produced a lot of pollutants.

3.3. Total suspended particulate matter (TSPM)

A significant variation in concentration of TSPM was observed with highest concentration (44.54 µg m^{3-1}) in Nauni village, followed by Samror (42.56 µg m^{3-1}), Serbanera (36.96 µg m^{3-1}) and Nagali (29.55 µg m^{3-1}) (Table 4).

Again the higher concentration of TSPM in Nauni and Samror villages might be attributed to fuelwood-based cooking, smoking and incense burning inside the house, ongoing construction work and dumping of building materials like sand and grit on the roadside and excavation activities. Junaid et al. (2017) reported that improper ventilation system design in houses has a significant impact on indoor air quality. Owing to the abundance of natural cover and the lack of vehicle activities and mobility, Nagali village had the lowest concentration of TSPM.

3.4. Nitrogen dioxide (NO_2)

The village Nauni has the highest NO_2 concentration (12.54 µg m^{3-1}), followed by Samror (10.01 µg m^{3-1}) and Serbanera (9.99 µg m^{3-1}). Nagali village had the lowest concentration (8.28 µg m^{3-1}), which was at par with NO_2 concentrations at Serbanera and Samror (Table 4). The NO_2 concentration of all the villages was within the permissible limits as described by CPCB.

The highest NO_2 concentrations in Nauni village might be attributed to vehicle emissions, parking near a home or garage and the use of farm machinery etc. According to Spengler et al. (2001), vehicle exhaust carrying nitrogen dioxide might reach a home via a connected garage. The concentration was low in Nagali village due to a lack of vehicular activities and an abundance of natural vegetative cover.

3.5. Sulphur dioxide (SO_2)

The SO_2 concentration in different villages was determined to be statistically significant (Table 4). The highest concentration (0.35 µg m^{3-1}) of SO_2 was found in Nauni, followed by Samror and Serbanera villages with concentrations of 0.33 and 0.32 µg m^{3-1}, respectively and Nagali with the lowest concentration (0.30 µg m^{3-1}). The concentrations of SO_2 at Nagali and Serbanera found at par with each other. Similarly, Nauni-Samror and Samror-Serbanera was found at par with one another.

The greatest SO_2 concentrations in Nauni village may be due to improperly vented gas appliances, heaps of cow dung near houses, cow sheds and kitchen outflow to open channels. According to Junaid et al. (2017), poor indoor air quality is not only associated with confined areas, but it may also be caused by problems in ventilation system design, which can carry pollutants from outside into inside spaces. The Nagali village had the lowest SO_2 concentration due to limited vehicle activity as well as the existence of increased vegetation, which absorbed the pollutant and resulted in a reduction in SO_2 concentration. The SO_2 concentration was determined to be quite low in comparison to the standard limits.

3.6. Air quality index (AQI)

It was found that rural areas of Solan district had a 'Good' indoor air quality index (Table 5). Nauni had the highest AQI (18.55) followed by Samror (17.0) and Serbanera (16.85), while Nagali had the lowest (12.22). The 'Good' AQI in the rural areas of Solan district was due to the fact that the inside air was clean and had just a small amount of Particulate Matters, SO_2 and NO_2 and good greenery and on average low vehicular concentration.

Table 5: Air quality index in the rural households

Sites	AQI	Ambient air quality
Nauni	18.55	Good
Samror	17	Good
Serbanera	16.85	Good
Nagali	12.22	Good
Solan district	16.15	Good

3.7. Factors responsible for affecting indoor air quality

3.7.1. Mode of energy used for cooking

Cooking with fuelwood accounted for 79.1% of all households, followed by LPG and fuelwood (62.5%). Cooking with fuelwood and dung cake was used by 58.3% of the households. Only 20.8% of household used LPG only for cooking, whereas 29.1% used three types of energy sources including LPG, electric induction and fuelwood (Table 6). Masekoameng et al. (2005) reported that fuel wood was the primary source of energy for cooking and heating, while paraffin and candles used for lighting.

3.8. Mode of ventilation in selected rural households

Among the total selected households 75% had a chimney and window in the kitchen, while 66.6% had a balcony/courtyard and at least two windows per room. However, 62.5% of households had a kitchen separate from the home, whereas 37.5% had a kitchen within the house. Windows, chimney and exhaust fan accounted for 37.5% of the home (Table 6). According to Junaid et al. (2017), poor indoor air quality was not just associated with confined rooms, but it could also be caused by problems in ventilation system or design, which might carry pollutants from outside into inside areas.

3.9. Indoor sources of smoke of selected households

More than 79.1% used fuelwood for heating and cooking and 75% of the households smoked inside the house. Dhoop smoke, which contains harmful particulates and volatile compounds, provided substantial health hazards to 66.6% of homes, whereas incense sticks were used by 33.3% of households (Table 6). One of the most important concerns in terms of health effect is indoor air quality. Stabile et al. (2017) reported that people are routinely exposed to high concentrations of contaminants indoors, resulting in serious health consequences from cigarette smoking.

3.10. *Mode of indoor insect/pest control measures used by selected households*

Several chemical management strategies were employed to control mites and pests in the house (Table 6). Insect and pest repellents/coils were used by 75% of households to get rid of mosquitoes, flies, spiders, cockroaches and ants. Households employed a range of multipurpose cleaners and disinfectants including kerosene, lizol, hit and others. Depending on the number of days, the frequency of disinfectant usage ranged from 8.3 to 41.6%. Approximately 41.6% of households used disinfection weekly followed by monthly, fortnightly and daily. In houses, various types of insects, pests and bacteria were found that were dangerous to people (Soundararaj, 1974).

3.11. Mode of household waste disposal in the selected households

Around 75% of households disposed of garbage in open areas, 58.3% burnt waste near their homes and 45.8% disposed of garbage near their homes. A small fraction of household, 41.6% used Panchayat provided dustbins (Table 6). Bency et al., 2003 reported that solid waste management caused unsanitary circumstances that might lead to a variety of microbiological and environmental problems.

3.12. Frequency of cleaning patterns inside the selected households

Carpets were used in 33.3% of the houses, doormats in 41.6% of the houses and both carpets and doormats were used in 25% of the houses. When it came to the use of carpets and mats, there was a lack of cleanliness. The primary reason for having doormats at the entrance was to prevent outside dust from entering the home through shoes or foot movement. All the respondents swept their house daily. Approximately 66.6% of respondents mop their floors

Table 6: Factors assessed for indoor air quality for the selected household

Sl. No.	Factors	Treatments	No. of respondents (N=24)	Per cent response
1.	Mode of energy source used for cooking	➢ Number of houses used fuel wood based cooking	19	79.1
		➢ Number of houses used only LPG for cooking	5	20.8
		➢ Number of houses used both LPG and fuelwood	15	62.5
		➢ Number of houses used dung cakes and fuelwood for cooking	14	58.3
		➢ Number of houses used LPG, electric induction and fuelwood	7	29.1
2.	Mode of Ventilation	➢ Kitchen within the house	9	37.5
		➢ Kitchen separate from the house	15	62.5
		➢ Kitchen having chimney and window	18	75.0
		➢ Kitchen having chimney and exhaust fan	12	50.0
		➢ Kitchen having windows, chimney and exhaust fan	9	37.5
		➢ House with minimum two number of windows per room	16	66.6
		➢ Houses with open balcony/courtyard	16	66.6
3.	Smoke sources	➢ Fuelwood burning for heating and cooking	19	79.1
		➢ Smoking practised inside house	18	75.0
		➢ Use of dhoop inside house	16	66.6
		➢ Use of incense stick inside house	8	33.3
4.	Insect/pest control measures	➢ Disinfectant used (chemicals)		
		• Sprays	5	20.8
		• Liquid Disinfectant	11	45.8
		• Insect and Pest repellent/coil	18	75.0
		➢ Frequency of disinfectant used		
		• Daily	2	8.3
		• Weekly	10	41.6
		• Fortnightly	4	16.6
		• Monthly	8	33.3
5.	Household waste disposal	➢ Dustbins provided by Panchayat	10	41.6
		➢ Waste disposed in open area	18	75.0
		➢ Waste disposed of nearby the house	11	45.8
		➢ Burning of waste nearby house	14	58.3
6.	Frequency of cleaning activity	➢ Houses used carpets	8	33.3
		➢ Houses used doormats	10	41.6
		➢ Houses used carpets and doormats	6	25.0
		➢ Daily of sweeping	24	100
		➢ Daily of mopping	16	66.6
		➢ Houses clean its carpet and mat weekly	0	0
		➢ Houses clean its carpet and mat fortnight	6	25.0
		➢ Houses clean its carpet and mat monthly	18	75.0
		➢ Houses having shoes open at the entrance	14	58.3
7.	Dampness in the house	➢ Number of houses having dampness due to rain from wall roofs, floors and faulty plumbing	14	58.3
		➢ Number of houses having no dampness	10	41.6
8.	Use of perfumes and air fresheners	➢ Number of houses used perfume	16	66.6
		➢ Number of houses used no perfume	8	33.3
		➢ Number of houses which use air freshener in summer	8	33.3
		➢ Number of houses which use air freshener in monsoon	11	45.8
		➢ Number of houses which use air freshener in winter	5	20.8

Table 6: Continue...

Sl. No.	Factors	Treatments	No. of respondents (N=24)	Per cent response
9.	Place of cowshed	➢ Cowshed near house	15	62.5
		➢ Cowshed away from house	5	20.8
		➢ Cowshed attached with house	4	16.6
		➢ Stall feeding of livestock in courtyard of house	14	58.3
		➢ Stall feeding of livestock away from house	8	41.6

daily and 75% clean their mats and carpets once a month. Matheson et al. (2003) observed that carpets enhanced exposure to allergens generated by home dust mites. Cleaning the house is an important activity for removing house dust mites. Foot movement was responsible for the bulk of the dust and dirt on the flooring(Maertenset al., 2004). Aside from that, the primary source of dust was the housemates' shoes. Opening shoes at the entrance suggested that respondents were conscious of cleanliness, which resulted in improved health and hygiene for family members. Data show that 58.33% of families open their shoes before entering the house (Table 6). This reduced the quantity of dust that entered the house and thereby caused reduction in proliferation of house dust mites.

3.13. Status of dampness in the selected households

Water leakage caused by rain was a common issue for 58.3% respondents. Water leaks, defective plumbing and poorly ventilated bathrooms may all result in dampness, which allows germs, mosquitoes and mould to grow rapidly (Table 6). Arundel et al. (1986) reported that excessive humidity levels in the home may quickly lead to mould growth, which can cause odor, respiratory discomfort and allergies. Dampness in the house has an impact on the health and comfort of the residents (Rao and Subrahmanyam, 2004). Water leaks from a roof or a wall also provide a favorable atmosphere for the proliferation of house dust mites because they increase the percentage of relative humidity in the interior environment (Harving et al., 1991).

3.14. Use of perfumes and air fresheners inside the selected households

There were 33.3% of households that did not use perfumes, compared to 66.67% of perfume user houses while 33.3, 45.8 and 20.8% of houses used air freshners in the summer, monsoon and winter season respectively (Table 6). Sarwar et al. (2004) stated that secondary pollutants generated by fragranced consumer products (such as air fresheners and cleaning supplies), as well as primary emissions of selected VOCs such as limonene and other terpenoids.

3.15. Effect of cowshed location on indoor air quality

Livestock had a significant impact in the spread of allergy disorders indoors. Approximately 62.5% of cowsheds are located near the house, 20.8% are located distant from the house and 16.6% are linked to the home. On the other side, 58.3% of household's stall feed animals in the courtyard, whereas only 41.6% of houses stall feed livestock away from the house (Table 6). According to Borlee et al. (2017), living around a significant number of animals increases the risk of airway obstruction. Furthermore, greater levels of ammonia in the air have been linked to acute lung function impairments in adults and asthmatic children living in livestock-heavy areas.

The decreasing order of different factors responsible for indoor air pollution as Smoke sources > Mode of Ventilation > Household waste disposal > Mode of energy source used for cooking > Dampness in the house > Frequency of cleaning activity > Use of perfumes and air fresheners > Place of cowshed > Insect/pest control measures.

Table 7: Rank of different factor responsible for indoor air quality

Sl. No.	Factors	No. of respondents (N=24)	Per cent response	Rank
1.	Smoke sources	15.25	63.54	I
2.	Mode of ventilation	13.57	56.54	II
3.	Household waste disposal	13.25	55.20	III
4.	Mode of energy source used for cooking	12.00	49.99	IV
5.	Dampness in the house	12.00	49.99	V
6.	Frequency of cleaning activity	11.33	47.22	VI
7.	Use of perfumes and air fresheners	9.60	39.99	VII
8.	Place of cowshed	9.20	39.99	VIII
9.	Insect/pest control measures	8.28	34.52	IX

4. CONCLUSION

The AQI in Solan District varied between 12.2 to 18.6, indicating 'Good' air quality. Nauni village had the greatest amount of contamination, while Nagali village had the lowest. The most significant element impacting IAQ was smoke from sources such as incense, dhoop, fuelwood burning, and indoor smoking, all of which posed health hazards. Insect and pest management measures had the least impact, although they remained a source of concern. To enhance indoor air quality, effective energy consumption and building solutions are needed.

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8. REFERENCES

Arundel, A.V., Sterling, E.M., Biggin, J.H., Sterling, T.D., 1986. Indirect health-effects of relative-humidity in indoor environments. Environmental Health Perspectives 65(351), 3–61.

Balakrishnan, K., Ramaswamy, P., Sambandam, S., Thangavel, G., Ghosh, S., Johnson, P., Mukhopadhyay, K., Venugopal, V., Thanasekaraan, V., 2011. Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Global Health Action 4(1), 5638.

Borlee, F., Yzermans, C.J., Aalders, B., Rooijackers, J., Krop, E., Maassen, C.B., Schellevis, F., Brunekreef, B., Heederik, D.,Smit, L.A., 2017. Air pollution from livestock farms is associated with airway obstruction in neighbouring residents. American Journal of Respiratory and Critical Care Medicine 196(9), 1152–1161.

Burnett, R., Chen, H., Szyszkowicz, M., Fann, N., Hubbell, B., Pope III, C.A., Apte, J.S., Brauer, M., Cohen, A., Weichenthal, S., Coggins, J., 2018. Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. In: Proceedings of the National Academy of Sciences 115(38), 9592–9597.

Chafe, Z.A., Brauer, M., Klimont, Z., Van Dingenen, R., Mehta, S., Rao, S., Riahi, K., Dentener, F., Smith, K.R., 2014. Household cooking with solid fuels contributes to ambient PM2. 5 air pollution and the burden of disease. Environmental health perspectives 122(12), 1314–1320.

Harving, H., Korsgaged, J., Dahl, R., 1991. House dust mites and associated environmental conditions in Danish homes. Allergy 48(2), 106–109.

Junaid, M., Syed, J.H., Abbasi, N.A., Hashmi, M.Z., Malik, R.N., Pei, D.S., 2017. Status of indoor air pollution (IAP) through particulate matter (PM) emissions and associated health concerns in South Asia. Chemosphere 191, 651–663.

Kampa, M., Castanas, E., 2008. Human health effects of air pollution. Environmental Pollution 151(2), 362–367.

Kankaria, A., Nongkynrih, B., Gupta, S.K., 2014. Indoor air pollution in India: Implications on health and its control. Indian Journal of Community Medicine 39(4), 203–207.

Karambelas, A., Holloway, T., Kinney, P.L., Fiore, A.M., DeFries, R., Kiesewetter, G., Heyes, C., 2018. Urban versus rural health impacts attributable to PM2. 5 and O3 in northern India. Environmental Research Letters 13(6), 064010.

Lawrence, A.J., Taneja, A., 2005. An investigation of indoor air quality in rural residential houses in India - a case study. Indoor and Built Environment 14(3), 321–329.

Maertens, R.M., Bailey, J.,White, P.A., 2004. The mutagenic hazards of settled house dust: a review. Mutation Research/Reviews in Mutation Research 567(2–3), 401–425.

Mage, D., Ozolins, G., Peterson, P., Webster, A., Orthofer, R., Vandeveerd, V., Gwynne, M., 1996. Urban air pollution in megacities of the world. Atmospheric Environment 30(5), 681–686.

Masekoameng, K.E., Simalenga, T.E.,Saidi, T., 2005. Household energy needs and utilization patterns in the Giyani rural communities of Limpopo Province, South Africa. Journal of Energy in Southern Africa 16(3), 4–9.

Matheson, M.C., Dharmage, S.C., Forbes, A.B., Raven, J.M., Woods, R.K., Thien, F.C., Guest, D.I., Rolland, J.M., Walters, H.E., Abramson, M.J., 2003. Residential characteristics predict changes in Der p1, Fel d1 and ergosterol but not fungi over time. Clinical and ExperimentalAllergy 33(9), 1281–1288. https://doi.org/10.1046/j.1365-2222.2003.01747.x.

Rao, Y.N., Subrahmanyam, Y., 2004. Planning and designing of residential buildings. Standard Publishers distributers, Delhi. Pp. 176–177.

Saiyed, H.N., Patel, T.S., Gokani, V.N., 2001. Indoor air pollution in India: a major environmental and public health concern. ICMR Bull 31(5), 1–9.

Sarwar, G., Olson, D.A., Corsi, R.L., Weschler, C.J., 2004. Indoor fine particles: the role of terpene emissions from consumer products. Journal of the Air & Waste Management Association 54(3), 367–377.

Smith, K.R., 1993. Fuel combustion, air pollution exposure, and health: The situation in developing countries. Annual Review of Energy and the Environment 18(1), 529–566.

Soundararaj, S., 1974. Cleanliness and care of house. A text book of Household Arts. Kalakshetra publications, 61–66.

Spengler, J.D., Samet, J.M., McCarthy, J.F., 2001. Indoor air quality handbook. New York: McGraw-Hill Professional.

Stabile, L., Fuoco, F.C., Buonanno, G., 2012. Characteristics of particles and black carbon emitted by combustion of incenses, candles and anti-mosquito products. Building and Environment 56, 184–191.