Association between Human Health and Indoor Air Pollution in Saudi Arabia: Indoor Environmental Quality Survey

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MS and MAK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FK, SA, SMAS, TG, AH, AASAA, MAAA, ASA, MHBSA and DFA collected data and managed the analyses of the study. Author MK contributed in literature search, questionnaire preparation and finalized the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

In many aspects of life quality, bio-contaminants and indoor air quality have had catastrophic consequences, including a negative impact on human health with an increased prevalence of
1. INTRODUCTION

Indoor air quality is one of the most significant factors affecting people’s health and well-being who inhale 10m³ of the air every day and spend between 80-95% of their lives indoors [1]. The air inhaled by the human is abundantly populated with microorganisms which form so-called bio-contaminants. Possible sources of biological contamination of indoor air include people, organic dust, various materials stored in the houses, and the air inflowing from the ventilation and air conditioning systems [2,3]. Biological contaminants are a form of air pollutants, present particularly in the indoor air that humans breathe [4,5].

Bio-contaminants can cause a wide range of adverse effects [6]. These include respiratory allergic reactions, asthma, and infectious diseases ranging from Influenza to Legionnaires disease, which damages lungs, intestines, kidneys, the central nervous system, and may even cause death to significant numbers of people [7,8,9]. Various diseases, including COVID-19, can also be spread to humans through bio-contaminants [10,11].

Almost one billion people, mostly women, and children are exposed to indoor air pollution levels that exceed the World Health Organization guidelines [12]. On a global scale, this amounts to three million deaths a year from indoor air. While ambient air quality has been a matter of debate and concern in the developing world, very little attention has been paid to indoor air quality in Kingdom of Saudi Arabia (KSA). It should be noted that the country faces other pressing health issues that compete for both resources and manpower.

Various diseases may be associated with indoor bio-contaminants [13,14]. However, only limited data are available on diseases associated with indoor bio-contaminants in KSA [15]. More specifically, there is no specific data available on season dependent bio-contaminant and their impact on human health. For the first time, the present proposal aims to evaluate the spectrum and concentration of bacteria, fungi, and mold in the indoor environment compared to the outdoor environment during different seasons in KSA and find out the health effect of people living in this environment. The data will help to control indoor bio-contaminant and will help to clean the environment. It will also help in the safety assessment of indoor residence/occupants of people of KSA.

Recently, the Kingdom of Saudi Arabia (KSA) has experienced tremendous population growth, as a result, the number of houses, masjids, schools, hospitals, hotels, offices, etc. has also increased significantly. However, limited data are available on the indoor pollution of these places. Therefore, the online questionnaire was distributed among Saudi Arabia residents to determine the indoor environment quality (IEQ) in their house. The research aimed to examine the associations between house IEQ and reporting of allergic respiratory reactions, asthma, and infectious diseases. We aimed to evaluate the quality of indoor air environment and find out the association between human health and indoor air pollution and also to assess the physical health status of a group of Saudi and non-Saudi populations during this pandemic. Also, we aimed to assess the most common health condition or symptoms associated with ventilation. A questionnaire was distributed online to test indoor air quality, ventilation status, common signs and symptoms of any allergy or mental status and their relationship to certain variables. A total of 362 respondents were included. Before living in the current home, flu or Influenza and chapped lips were more prevalent than allergies and chapped lips signs while living in the current home. (12.2% , 10.8% vs. 18.5% , 13.55% before and after respectively) Multiple colds were the second most common symptom (10.2%). Hoarse voice and headaches were the least common symptoms experienced; each constituted 4.4%. During the COVID-19 Pandemic, most respondents wore a facemask, approximately 76.5%; and almost one-third of respondents had bright natural light inside the current home (43.1%). The presence of natural light within the current home was significantly associated with symptoms experienced during living in the current house (p<0.05). Natural sunlight exposure could decrease allergic symptoms and minor health problems associated with poor ventilation and air quality indoors. In current living homes, the majority of respondents never used air purifiers (72.9 percent). In order to get attention from people to enhance the quality and ventilation mechanism of indoor air, special care and awareness of the effects of the use of air purifiers on human health is needed.

Keywords: Indoor air pollution; human health; Influenza & Respiratory allergies.
different symptoms (respiratory, lower respiratory, and general). Survey results can positively influence indoor environmental quality for occupants of existing as well as future buildings.

2. MATERIALS AND METHODS

Based on the protocol used by the World Health Organization (WHO) to identify health risks associated with housing, we conducted an online cross-sectional survey among currently living peoples of Hail, Saudi Arabia. A detailed questionnaire consisting of information on demographic and other variables was designed. Total 362 questionnaires were mailed in English and Arabic, both languages, to participants before taking consent from each participant.

There are several other IEQ elements and parameters that could have been included in this study. However, wherever reliable supporting data and affordable measuring instruments are available, this study has included such elements and parameters such as natural ventilation and natural light in an indoor environment.

There are several guidelines for protecting public health from risks due to several factors commonly present in indoor air; however, these are not generally acknowledged guidelines. Therefore, the authors have decided to use and adapt the WHO guidelines for the protection of public health [16].

2.1 Statistical Analysis

The results are presented in frequencies and percentages. The Chi-square test was used for comparisons. The p-value<0.05 was considered significant. All the analysis was carried out on SPSS 23.0 version (Chicago, Inc., USA) [17].

3. RESULTS

More than half of the respondents were between 18-29 years of age (55.2%) and were females (59.1%). Most of the respondents were graduates (55%) and (57.2%) were retired. About one-third of the respondents were married (35.1%). More than half of the respondents were currently living in Hail (59.9%). Only 10.5% of respondents were cigarette and shisha (Hookah) smokers (Table 1).

About one-third of respondents were living in the current house for 0-5 years (33.7%), followed by 5-10 years (29.8%), 10-20 years (26.2%), 20-40 years (8.8%), and >40 years (1.4%). More than half (57.7%) of respondents spent >12 hours at the current house, followed by 12 hours (27.9%) and 6 hours (14.4%) (Table 2).

Fig. 1 shows respondents' distribution according to those who suffered from respiratory diseases/conditions before and currently living at the house. Allergies were the most common
disease/condition (18.5%), and chapped lips were the second most common disease/condition (13.5%) during current living home. Pharyngitis was the least common disease/condition (1.7%) during the current living home. However, Influenza (flu) was the most common disease/condition (12.2%) before living at the current home, and Chapped lips were the second most common (10.8%). Pneumonia was the least common disease/condition (2.8%) before living at the current home.

Table 3 shows the distribution of respondents according to symptoms living at the current house. The sore throat was the most common symptom experienced living at the current house (11.3%), and Multiple colds were the second most common symptom (10.2%). Hoarse voice and Headaches were the least common symptom experienced; each constituted 4.4%. More than half of respondents (65.5%) had duration of symptoms were seasonal, and in the spring season, 55.4% had symptoms. Cleaning agents were the leading cause of experiencing symptoms, constituting 24.5%. The duration of the presence of symptoms was in all of life among 50.6% of respondents. Symptoms go away by the morning was opined by 63.9% of respondents, and symptoms go away when on vacation was opined by 57.4% of respondents. The majority of respondents have some symptoms while living at their current house.

Table 1. Basic profile of respondents

| Demographic profile               | No. (n=362) | Percentage (%) |
|----------------------------------|-------------|----------------|
| **Age in years**                 |             |                |
| Less than 18                     | 48          | 13.3           |
| 18 – 29                          | 200         | 55.2           |
| 30 –40                           | 79          | 21.8           |
| 41 – 50                          | 29          | 8.0            |
| 51 – 60                          | 6           | 1.7            |
| **Gender**                       |             |                |
| Male                             | 148         | 40.9           |
| Female                           | 214         | 59.1           |
| **Education**                    |             |                |
| High school                      | 133         | 36.7           |
| Intermediate                     | 7           | 1.9            |
| Graduate                         | 199         | 55.0           |
| Post graduate+                   | 23          | 6.4            |
| **Occupation**                   |             |                |
| Employed                         | 114         | 31.5           |
| Housewife                        | 18          | 5.0            |
| Unemployed                       | 16          | 4.4            |
| Student                          | 207         | 57.2           |
| Retired                          | 5           | 1.4            |
| Others                           | 2           | 0.6            |
| **Marital status**               |             |                |
| Married                          | 127         | 35.1           |
| Single                           | 235         | 64.9           |
| **Have children**                |             |                |
| Yes                              | 108         | 29.8           |
| No                               | 254         | 70.2           |
| **Currently living in Hail**     |             |                |
| Yes                              | 217         | 59.9           |
| No                               | 145         | 40.1           |
| **Cigarette smoking**            |             |                |
| Yes                              | 39          | 10.8           |
| No                               | 323         | 89.2           |
| **Smoke shisha (Hookah)**        |             |                |
| Yes                              | 38          | 10.5           |
| No                               | 324         | 89.5           |
Table 2. Distribution of respondents according to living information at current house

| Living information at current house | Number (n=362) | %  |
|-----------------------------------|---------------|----|
| **Duration of living**            |               |    |
| 0 - 5 Years                       | 122           | 33.7|
| 5-10 Years                        | 108           | 29.8|
| 10-20 Years                       | 95            | 26.2|
| 20-40 Years                       | 32            | 8.8 |
| More than 40 Years                | 5             | 1.4 |
| **Approximately time spending at house** |       |    |
| 6 hours                           | 52            | 14.4|
| 12 Hours                          | 101           | 27.9|
| More than 12 hours                | 209           | 57.7|
| **Rating the indoor air quality** |               |    |
| Average                           | 115           | 31.8|
| Good                              | 227           | 62.7|
| Poor                              | 20            | 5.5 |

The majority of respondents never used humidifiers (72.4%) and air-purifier (72.9%) at current living homes. About one-fifth of respondents occasionally used humidifier (18.5%) and air-purifier (18.2%) at current living home. Only 6.4% of respondents regularly used humidifiers, and 7.5% periodically used purifiers at current living homes (Table 6).

4. DISCUSSION

According to the World Health Organization [16], 4.2 million deaths worldwide were due to ambient air pollution in 2016. This caused non-communicable diseases, including lung cancer, chronic obstructive pulmonary disease, heart disease, and stroke. The present study aimed at correlating indoor environmental quality and different symptoms as well as the personal experiences of residents of houses. This study's limitations exist in the fact that few scientific research data are available in Saudi Arabia. The present study explored the impact of indoor environmental quality (IEQ) with different types of symptoms, including allergic rhinitis, allergies, chapped lips, influenza(flu), sinusitis, asthma, laryngitis, pharyngitis, pneumonia and unusual thirst etc. This study examined associations between indoor environmental quality (IEQ) problems in homes and symptom reported by respondents, and whether associations became stronger when participants related symptoms to the home environment. We found associations between the overall score of IEQ problems and increased reporting of respiratory and general symptoms in respondents. Some associations were also observed between IEQ indicators and lower respiratory as well as skin symptoms, but not eye symptoms.
Table 3. Distribution of respondents according to symptoms living at current house

| Symptoms experienced                      | No. (n=362) | %    |
|-------------------------------------------|-------------|------|
| Wheezing (except cold)                    | 21          | 5.8  |
| Sinus infection                           | 26          | 7.2  |
| Multiple colds (more than four)           | 37          | 10.2 |
| Sore throat                               | 41          | 11.3 |
| Shortness of breath                       | 39          | 10.8 |
| Hoarse voice                              | 16          | 4.4  |
| Migraines                                 | 27          | 7.5  |
| Headaches (at least 2/month)              | 16          | 4.4  |
| Burning or irritated eyes                 | 17          | 4.7  |
| Sneezing attacks                          | 22          | 6.1  |
| None                                      | 113         | 31.2 |

| Duration of symptoms                      | n=249       |      |
|-------------------------------------------|-------------|------|
| Seasonal                                  | 163         | 65.5 |
| Round the years                           | 37          | 14.9 |
| Both                                      | 49          | 19.6 |

| Seasons                                   | n=249       |      |
|-------------------------------------------|-------------|------|
| Fall                                      | 46          | 18.5 |
| Spring                                    | 138         | 55.4 |
| Summer                                    | 61          | 24.5 |
| Winter                                    | 53          | 21.3 |

| Causes                                    | n=249       |      |
|-------------------------------------------|-------------|------|
| Air-conditioning                          | 26          | 10.4 |
| Cold day                                  | 43          | 17.3 |
| Alcohol                                   | 49          | 19.7 |
| Chemical Fumes                            | 51          | 20.5 |
| Dry weather                               | 13          | 5.2  |
| Windy day                                 | 59          | 23.7 |
| Mold or mildew                            | 27          | 10.8 |
| Cleaning agents                           | 61          | 24.5 |
| Wet weather                               | 27          | 10.8 |
| Hot day                                   | 46          | 18.5 |
| House dust                                | 55          | 22.1 |

| Time of the day symptoms become worse     | n=249       |      |
|-------------------------------------------|-------------|------|
| Morning                                   | 92          | 36.9 |
| Afternoon                                 | 89          | 35.7 |
| Evening                                   | 96          | 38.6 |
| Night                                     | 91          | 36.5 |

| Duration of presence of symptoms          | n=249       |      |
|-------------------------------------------|-------------|------|
| Months                                    | 56          | 22.5 |
| Years                                     | 67          | 26.9 |
| All of life                               | 126         | 50.6 |

| Symptoms go away by the morning           | n=249       |      |
|-------------------------------------------|-------------|------|
| Yes                                       | 159         | 63.9 |
| No                                        | 90          | 36.1 |

| Symptoms go away when on vacation         | n=249       |      |
|-------------------------------------------|-------------|------|
| Yes                                       | 143         | 57.4 |
| No                                        | 106         | 42.6 |

| Have any health problems or allergies that might account for the above symptoms | n=249 |      |
|---------------------------------------------------------------------------|--------|------|
| Yes                                                                       | 185    | 74.3 |
| No                                                                        | 64     | 25.7 |

#Multiple response
Table 4. Distribution of respondents according to medications which they are currently taking on a daily or weekly basis while living at current house

| Medications that are currently taking on a daily or weekly basis living at current house | No. (n=362) | %  |
|---------------------------------------------------------------------------------------|-------------|----|
| Antidepressants                                                                       | 31          | 8.6|
| Decongestants                                                                         | 25          | 6.9|
| Pain relievers                                                                        | 81          | 22.4|
| None                                                                                  | 225         | 62.2|

Table 5. Distribution of respondents according to current housing condition and its association with any symptom experienced

| Current housing condition | No. (n=362) | Symptom | p-value* |
|---------------------------|-------------|---------|----------|
|                           |             | Present | Absent  |          |
|                           | No. | %   | No. | %   | No. | %   |
| Natural light inside current home | | | | | | |
| Dim light                 | 62  | 17.1| 50  | 80.6| 12  | 19.4| 0.04* |
| Just light                | 125 | 34.5| 79  | 63.2| 46  | 36.8|
| Bright light              | 156 | 43.1| 110 | 70.5| 46  | 29.5|
| Too bright                | 13  | 3.6 | 8   | 61.5| 5   | 38.5|
| Too dim                   | 6   | 1.7 | 2   | 33.3| 4   | 66.7|
| There been any renovation/demolition related activities occurred in or near current living home within past weeks | | | | | | |
| Yes                       | 95  | 26.2| 65  | 68.4| 30  | 31.6| 0.92 |
| No                        | 267 | 73.8| 184 | 68.9| 83  | 31.1|
| There been any evidence of water leaks or visible sign of moisture in current living home | | | | | | |
| Yes                       | 65  | 18.0| 50  | 76.9| 15  | 23.1| 0.11 |
| No                        | 297 | 82.0| 199 | 67.0| 98  | 33.0|
| Home situated near any of these | | | | | | |
| Farm                      | 21  | 5.8 | 17  | 81.0| 4   | 19.0| 0.008* |
| Industrial area           | 13  | 3.6 | 9   | 69.2| 4   | 30.8|
| Vacant land               | 79  | 21.8| 66  | 83.5| 13  | 16.5|
| Water source              | 13  | 3.6 | 7   | 53.8| 6   | 46.2|
| Not applicable            | 236 | 65.2| 150 | 63.6| 86  | 36.4|
| Any other exposure such as an additional job/hobbies, e.g. gardening/farming, etc | | | | | | |
| Yes                       | 39  | 10.8| 26  | 66.7| 13  | 33.3| 0.76 |
| No                        | 323 | 89.2| 223 | 69.0| 100 | 31.0|

*Chi-square test, *Significant

More than 75% of respondents were 18-40 years old and about 59.1 % were female. Most of the respondents did not have any symptoms before or after living in their current home. The most prevalent symptoms were Allergies (18.5%), chapped lips (13.5%), Influenza (flu) (9.4%), and sinusitis 7.2% among respondents living in current houses.

We further tested whether associations between IEQ and symptoms were reported in relation to current house and before living in the current houses. The present study found that the associations between IEQ and symptoms related to the current house environment were somewhat stronger in magnitude compared to associations with symptoms reported before living in the current houses. To the best of our knowledge, these associations have not been tested previously.

Another study conducted in Delhi’s industrial area shows that 30% of the population has respiratory or pulmonary system symptoms due to a large amount of time (80%) spend indoors [18].
Fig. 2. Distribution of respondents according to symptoms experienced which may be related to work environment or living at current house (Multiple response)

Table 6. Distribution of respondents according to use of humidifier at current living home

| Use of humidifier at current living home | Use of humidifier | Use of air purifier |
|-----------------------------------------|------------------|--------------------|
|                                        | No. (n=362)      | %                  | No. (n=362) | %        |
| Never use                               | 262              | 72.4               | 264         | 72.9     |
| Use occasionally                         | 67               | 18.5               | 66          | 18.2     |
| Use regularly in all-season              | 23               | 6.4                | 27          | 7.5      |
| Use regularly in summers                 | 6                | 1.7                | 1           | 0.3      |
| Use regularly in winters                 | 4                | 1.1                | 3           | 0.8      |

Fig. 3. Distribution of respondents according to Covid-19 parameters
In this impact assessment evaluating household air pollution's adverse health effects, we report several important observations. Household air pollution is associated with an increased risk of adverse health effects, with the strongest association observed for allergies and chapped lips [19]. As more than half of the respondents had a seasonal period of symptoms and had symptoms in the spring season. A similar report was also published by Li and co-workers [20].

Respondents reported various symptoms such as multiple colds (more than four), sore throat, shortness of breath etc. Similar finding were also reported by various researchers (Singleton et al. 2017); [21].

5. CONCLUSION

More than one-third of respondents had little natural light inside the current home. Allergies were the most common disease/condition. The sore throat was the most common symptom of living in the current house, and the second most common symptom was multiple colds. Natural light within the current home and home near industrial area was significantly associated with symptoms experienced during living in the current house (p<0.05).

CONSENT

As per international standard or university standard, Participants’ written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

The study was approved by the institutional ethical committee (number 55456/5/41 dated August 19, 2020).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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