

# Evaluation of Indoor Air Quality in Residential Spaces During COVID-19 in Bahrain

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**Abstract** Indoor Air Quality (IAQ) plays a tremendous role in affecting user comfort, health, behavior, and overall satisfaction. It is very important as it can be a cause for concern and troublesome in the long term if not treated in advance. To study user satisfaction with IAQ, variables such as human health, behavior, and circulation patterns were closely addressed. Moreover, residences were selected as the area of focus as most of one's time is spent at home. This study incorporated residents of Bahrain above the age of 20 who were segregated based on whether they were working or non-working. The study aimed at addressing user satisfaction with IAQ in Residences of Bahrain during the 'COVID-19 pandemic', especially, as residents spent a large amount of time at their households during the lockdown period. The research involved analyzing issues of IAQ both internationally and regionally, which was later implemented in the local context of Bahrain. Questionnaires and Interviews about user satisfaction with IAQ were conducted with a large group of residents and covered both quantitative and qualitative approaches. The data collected was analyzed manually. Altogether the study showed that most of the residents are satisfied with their experience of IAQ in their households despite facing pollution to a certain extent. Meanwhile, a smaller group of residents faced issues that directly affected their health, behaviors, and movement patterns which was contributed by the IAQ of their households. Nevertheless, the research helped to gain a deeper understanding of user satisfaction in general and gave new insights into issues faced by residents in terms of air quality.

**Keywords** User Satisfaction, IAQ, Households, COVID-19, Bahrain

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## 1. Introduction

Indoor Air Quality/ IAQ is considered as the degree of quality of air that is present in the indoor environment [1]. It is interesting to note that humans have tried hard to build comfortable and safe dwellings over the years [2]. The emergence of industrialization as well as technical involvement has led to the current scenario of buildings that are complex and robust and are used widely for different purposes. A study found that humans spend most of their time (80-90%) indoors in most of the industrialized countries. It is crucial to note that a poor indoor environment results in occupants who are unsatisfied and uncomfortable [2]. Several studies have been widely conducted both internationally and regionally addressing the issue of IAQ. However, previous research on indoor air pollution in Bahrain focused on occupants' satisfaction in Governmental Buildings.

In terms of IAQ within residential spaces during COVID-19, there exists a research gap on this issue in the context of Bahrain despite having significant difficulties, which will be explored through the research. As a result, this research aims to address user satisfaction with IAQ in Bahrain. This research is focused on addressing several materials exploring the user experience and satisfaction of IAQ, particularly in residential spaces. Based on the

literature review synthesis done on an international and regional basis, this will be further investigated in the context of Bahrain during COVID-19 when people stayed indoors more often. The data collected will be further analyzed in the methodology section to gain an in-depth understanding and a conclusion is drawn addressing both the quantitative and qualitative analysis.

## 2. Literature Review

### 2.1. Indoor Air Quality

IAQ is a factor that can be managed, and this is possible by increasing the ventilation within the indoor environment [3]. Yet another method is to reduce the load of air pollutants present in the air. Interestingly, to reduce the load of air pollutants present in the air, one can use the method of ventilation. Ventilation can be used to exchange/remove contaminants and carbon dioxide that are present. However, poor IAQ does have a strong connection between poor human health and productivity [1]. Notably, cities that are of greater concern regarding indoor air pollutants are those with high ambient air pollutant levels [4]. Interestingly, people living in those regions with moderate climatic conditions are used to opening windows and doors during warm seasons [5]. As a result, it is rational to have the advantage of manually switching off ventilation systems. It is noted that to decide regarding ventilating living spaces, climate also plays a role. Notably, for several years, outdoor air was appraised as fresh air [6].

There have been studies done extensively on Indoor Air pollution in houses [7]. From the perspective of the studies conducted, it can be concluded that while there are approaches to IAQ in terms of climatic factors, the studies conducted focused on internal factors such as contaminants/pollutants in the air. Therefore, it is significant to study IAQ in terms of various other factors including how occupants experience Indoor Air, the contribution of external factors, and its impact on health, spatial experience, behavioural and movement patterns. Thus, being able to gain new insights and dimensions into the issue.

### 2.2. IAQ Experience in a Global Context

A study conducted in Slovakian Homes found that the users of thermally insulated houses without artificial ventilation were found to be often dissatisfied with indoor air quality [8]. On the other hand, another study conducted argued that there was no connection found about user satisfaction in terms of temperature in Lithuanian houses [6]. Interestingly, it was studied that people might suffer from a high possibility of inhalation exposure risk in rural homes that burn solid fuels which results in negative health outcomes. Other factors that contributed negatively include Cooking and/or heating fuel, Household fuel consumption,

Cooking oil, Smoking, Human activities, Air conditioning, etc. [9]. In addition, key factors affecting IAQ are found to be temperature and humidity concerning human comfort and health [6]. It is noticed that relative humidity ranging between 30% and 70% in residential buildings results in comfortable conditions. The number of users affecting the indoor climate and variations in user experiences also occur based on several factors that need to be investigated further [6].

It is found that insights and opinions regarding spatial and environmental qualities play a role in influencing how user experiences have drifted with time [10]. There exists a need for a legible understanding of the role, definition, contribution, connections, etc. of users to understand contentment, beauty, ergonomics, production, etc. So often, not only are today's buildings built without the world in mind, but they also ignore the occupant. In our buildings, we purposely construct static, standardized, neutral conditions, sometimes deviating people from nature and the natural environment's inherent cycles. The simulation of indoor penetration of PM10 and PM2.5 indicates that outdoor air is not a major source of particulate emissions in indoor areas and will also remain negligible in the future as the trend continues to decrease. The sources in the indoor region are of much greater significance in terms of visibility here [6]. Ventilation rate and carbon dioxide concentration are the most widespread and widely accepted proxies for IAQ. The level of ventilation, however, depends heavily on the severity of the emissions and thus the level of exposure influences the effects on humans [10]. It is important to understand how there exists an opportunity to create comfortable and healthy indoor environments [7].

Interestingly, in 2016, 396 students replied to a questionnaire on their health, comfort, other personal variables, and housing conditions in a Dutch study on student homes at three technical universities in the Netherlands. It was found that 33% of respondents suffered from rhinitis, which was found to be positively linked to having a family history of rhinitis and less than one year old particle board furniture in the bedroom after change [11]. The discomfort, however, was negatively linked to individuals who regularly worked out, and to those who did not have pets. Finally, opening the bedroom windows at least once a week has also been related to a decreased risk of rhinitis [11]. A relatively large proportion of building inhabitants still complain of issues and symptoms related to inadequate air quality, despite many efforts to improve IAQ in buildings. However, this proportion decreased in the 1990s after the studies [10]. A study conducted in governmental buildings in Bahrain showed that users were not strongly satisfied with their office spaces in terms of Indoor Environment Quality [12]. On the other hand, in another study conducted, three factors that proved to affect IAQ in residential areas were Outdoor Air Quality, User activity in buildings and buildings and construction materials, tools and furniture [13]. Whereas, Thermal

comfort, Air quality, Lighting, Acoustic quality, Office layout, Office furnishings, Cleanliness and maintenance, and Overall satisfaction were the Indoor Environment Quality Dimensions used to evaluate Occupant Satisfaction in the case of governmental buildings [12]. It is crucial to note that work on IAQ in buildings has concentrated on minimizing adverse effects, although very little has been done to encourage positive qualities such as happiness and well-being [10].

These studies give an understanding of how user experiences and satisfaction vary regionally as well as based on different factors that affect user experiences. Thus, it is vital to recognize user experience in the context of Bahrain and study the factors that contribute to affecting IAQ.

### 2.3. Impact of IAQ in Residential Spaces

We usually tend to hear about the negative impacts of IAQ such as sick building syndrome, buildings that are sealed and do not come with operable windows, lack of lighting, and so on. Those spaces are linked with the natural environment and give in sense of place and content to the user. Thus, it is necessary to focus on the positive impacts in indoor environments as well as understand which type of spaces give a sense of place, comfort, and happiness to different users in terms of IAQ [10]. Several pollutants such as emissions from activities, buildings, furnishing materials, products used for cleaning, etc. have been responsible for provoking issues such as headaches, skin symptoms, and tiredness [11]. On the other hand, in another study conducted, it was found that occupants never voted 'uncomfortable' regarding their indoor environment [14]. Hence, it is gathered that there exists a variety of opinions regarding user satisfaction of IAQ.

### 2.4. Relationship between IAQ and COVID-19 in Residential Spaces

One of the human health threats in the Gulf Cooperation Council (GCC) countries is Indoor Air Pollution (IAP) [7]. In these countries, people spend a large amount of their time in indoor environments because of adverse weather conditions, such as elevated air temperatures, high relative humidity, and natural disasters, such as dust storms. Moreover, the generation of physical and biological aerosols from air conditioners, cooking operations, the burning of Arab incense, and the overcrowding caused by pilgrimage programs are common causes in this area of low-quality indoor air. Thus, individuals living in the GCC nations are highly exposed to indoor air contaminants due to the penetration of outside sources as well as separate indoor sources [7]. The epidemic coronavirus disease (COVID-19) is a global pandemic that scares the entire world with the sudden appearance and rapid spread of new coronavirus viruses (2019-nCoV) or (SARS-CoV-2) [15]. Smoking in the home or indoor atmosphere by cigars, bidis,

and pipes is also another responsible factor for increasing smoky indoor environments, which was a risk factor for COVID-19 for children under 5 years [15]. There is a relationship between indoor cooking fuel used with biomass and the Coronavirus disease, as the coronavirus has been associated with IAP and a smoky climate [1]. Similarly, inhalation of indoor air toxins is found to cause cardiorespiratory, coronary, and lung cancer disease mortality, and morbidity [7].

Some studies have shown that maintaining high air quality in bedrooms leads to improved sleep quality and improved cognitive output for the next day [16]. As air temperature and humidity are decreased and airspeed is increased, beneficial effects on perceived air quality can be enhanced [17]. Moreover, improving air quality can reduce the intensity and prevalence of acute health symptoms reported by occupants, including irritation of mucous membranes, problems with airways, headaches, difficulty concentrating, fatigue, allergies, asthma, etc. [3].

It is also found that humans tend to spend 90% of their time in indoor environments [7]. Yet another factor related to IAQ in households is the involvement of water pipes. Tap water is widely used by residents in their dwellings for a wide range of purposes such as cooking, washing, humidifying, etc. In addition, it is derived that the link between indoor air and tap water has the possibility of contaminant exposure [18]. Hence, it is necessary to study which of these factors contribute to the user experiences and comfort whilst being indoors in their household, respectively.

Interestingly, the perception of IAQ reported in standardized occupant interviews indicates that occupants did not perceive air quality in summer or winter to be significantly fresh or significantly satisfactory. Whereas results indicate that the air was viewed by occupants as relatively dry and still during the summer months, which could have repercussions for overall comfort [19]. The air quality was viewed by at least one occupant as substantially unsatisfactory, which is a cause for concern. These findings show convergence with the results of measurements of IAQ and illustrate the need for an immediate analysis of strategies for energy-efficient design and the effect on the quality of indoor air [19]. Since the sources and activities of external and internal air pollutants may vary significantly between GCC countries, there exists a review that provides an in-depth analysis of indoor air pollution according to different geographical locations including Bahrain, Kingdom of Saudi Arabia (KSA), Kuwait, Oman, Qatar, and United Arab Emirates (UAE). Previous reviews have shown that the main indoor air contaminants in the GCC countries are particulate matter (PMs), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), and heavy metals [7].

Homes are environments that through the facilities and systems of the buildings, can give the occupant health and comfort. The provision of health and comfort in

energy-efficient retrofitted homes needs to be achieved while retaining a "low" consumption of energy through the efficiency of the building and its systems. Such retrofits, however, are seldom carried out by taking into consideration the occupants' desires and needs and the impact of occupant behavior [12]. In indoor environments in UAE, different forms of air pollutants were found, where these pollutants were released from household products, kitchen operations, infiltration from environmental sources, incense burning, smoke, and overcrowding [7]. Yet another study in the context of Oman showed the principal source of indoor air pollution is the infiltration of environmental contaminants which is also due to industrial development and large construction [7]. Thus, highlighting the link between COVID-19 and IAQ, especially in the houses.

## 2.5. Impact of IAQ in Bahrain

While Bahrain has recognized the significance of the IAQ since the 1980s, it has the lowest number of studies on indoor air pollution [7]. Bahrain is a GCC member with the least population and real estate investment, as demonstrated by the second-lowest per capita GDP among the other countries in the region. While Bahrain has recognized the significance of the IAQ since the 1980s, the area has the lowest number of studies on indoor air pollution [7]. Work on IAQ in buildings has concentrated on minimizing adverse effects, although very little has been done to encourage positive qualities such as happiness and enjoyment. This includes understanding indoor air composition and how various species work to create an atmosphere conducive to well-being. Studies have discussed how the inclusion of fragrances may accomplish this, but this can also have negative effects [10]. In Bahrain, air quality studies are different compared to the rest of the GCC countries, where PM<sub>10</sub>, PM<sub>2.5</sub>, radon, VOC, PAHs, and bioaerosols are involved in indoor air pollution measurements and characterizations [7]. In addition, in terms of organizations with remote working environments for employees, it is claimed that the environment needs to be enhanced so that the employees feel safer and more secure. Thus, making them feel good while they are working and motivating them to do more, will have a great effect on increasing employee performance [20].

Until the first of February 2020, Bahrain thought COVID-19 was just a passing fog. However, the outbreak has adversely affected the mental and moral well-being of students in Bahrain [21]. In terms of Air Pollution, Bahrain has a PM level above the recommended level by WHO and the Air Pollution Level is highlighted as unhealthy. Therefore, it is critical to identify the causes and effects on occupants [22], [23]. Though it has affected users in different ways, the studies conducted have not evaluated the impact of IAQ in residential spaces, where users spent

most of their time during the pandemic, in terms of working, studying, and doing other activities. Hence, this research aims to tackle the areas of gap in the literature regarding IAQ in households, specifically in the context of Bahrain. It intends to focus on user experience and satisfaction when being indoors.

All in all, there exist several theories based on the above works of literature that examine user satisfaction with Indoor Air Quality. This research intends to connect different theories studied and analyze the context of Bahrain during the COVID-19 Pandemic. It is argued that occupants in the gulf particularly are exposed to IAQ threats as pollutants are caused by both internal and external influences [7]. Elevated air temperatures, high relative humidity, and natural disasters, such as dust storms affect IAQ as discussed above [7]. It is necessary to analyze this aspect in the case of Bahrain and identify whether external factors related to climate affect user satisfaction or not.

## 2.6. Hypothesis Development

This research focuses on IAQ within households in Bahrain during the COVID-19 pandemic and how occupants experience the spaces in terms of Air Quality. The main hypothesis is understanding user satisfaction with Indoor Air Quality inside their homes. The variables include studying their spatial and sensory indoor experiences in terms of IAQ, understanding behavioral and circulation patterns as well as determining whether there exist any health discomforts that lead to dissatisfaction with IAQ. The primary goal is to collect data, analyze and evaluate user satisfaction concerning IAQ in households. However, before reaching this goal, there exists several stages of hypothesis variables are unlocked. Understanding human behavioral patterns is necessary to determine their satisfaction/comfort. Having said that, these behavioral patterns can be tackled only by understanding the various activities performed by the occupant which leads to certain movements or behaviors.

In addition, user satisfaction due to health factors is also to be derived. This could be derived by understanding which factors affect health, whether it is due to external/internal pollutants, and analyzing which factor that exists indoors causes health issues that directly affect user satisfaction with that dwelling. Lastly, user satisfaction due to indoor sensorial and spatial experiences is also observed and analyzed. This gives an understanding of how the occupant perceives his dwelling and how he experiences it through his senses, thus contributing to his level of satisfaction. This is done by addressing one's ability to be productive, functional, etc. (Figure 1). These methods and stages are further mentioned in detail in the following section.

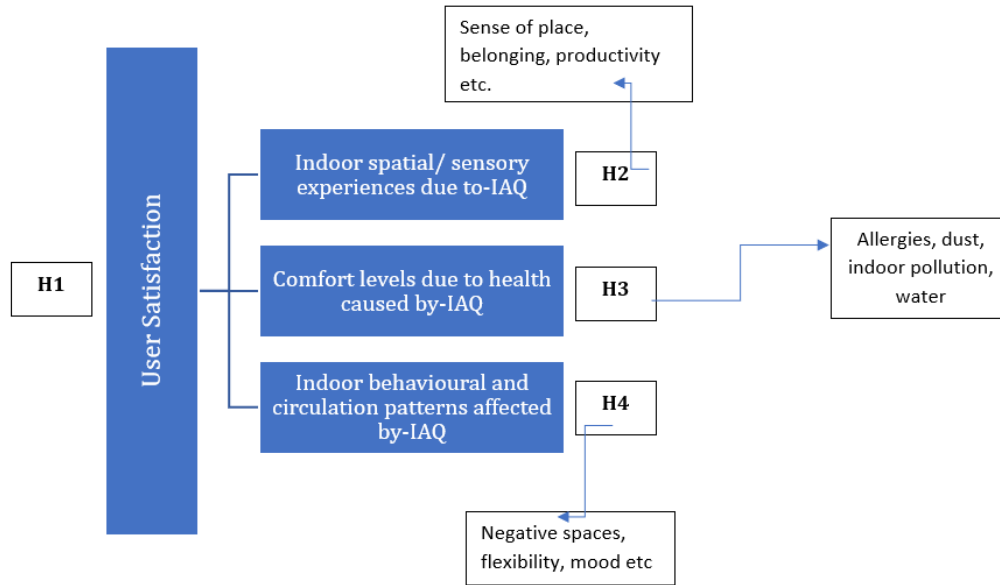


Figure 1. Hypothesis Development

### 3. Materials and Methods

#### 3.1. Introduction

This section focuses on the research methodology selected to study Indoor Air Quality in households and the methods used for the research. It also gives an overview of the approach taken to address the hypothesis, sample selection, selection criteria, and so on. The Research design selected is causal/explanatory research. This helps to investigate the cause-effect relationship of user satisfaction due to indoor air quality. Moreover, causal research is selected in this context as it is necessary to observe the variation in variables that can affect user satisfaction in people. The research design includes mixed-method research and includes a combination of both Qualitative and Quantitative approaches. The quantitative approach used here helps to gain insight and analyze the statistical data collected through an online questionnaire. On the other hand, the quantitative approach is tackled by having one-on-one in-depth interviews with participants, to understand their viewpoints and feedback which they might not elaborate freely through a questionnaire. Interviews are analyzed using coding.

This approach will provide relevant information on the research question and hypothesis as the interviews provide a subjective point of view, with in-depth reasoning, and most importantly each participant's response is based on his/her household. As a result, contextualization is developed through this quantitative study. Most importantly, as they describe their emotion through words, it adds to a deeper value. It is narrative and helps to form a storyline for each participant and touches on phenomenological aspects. Ethnographic research is conducted by studying and interacting with the participant

by addressing their real-life environment. However, the quantitative analysis also provides relevant information. Though the answers are very objective, it helps to generalize, and group people based on their opinions and points of view. Such an approach will also help to complete the job efficiently as the main hypothesis in this research is User Satisfaction of IAQ in households and to study the variables (Spatial Experience, Health, Behaviour Patterns) and their inter-relationship which alters their satisfaction, mixed-method research helps to tackle each variable with a different mode of studies (Table 1).

Table 1. Research Instruments for the Study

Phenomenology	Health Concerns	Behavioral Patterns	User Satisfaction
Productivity	Indoor Factors	Flexibility	Overall satisfaction
Spatial Experience	External Factors	Daylight, ventilation	Fusion of variables
		Metabolic activities	Satisfaction during the pandemic. Likert Scale of point 5

#### 3.2. Population

The population defined is all working residents of Bahrain. It was found that Bahrain's working population by the end of 2019 reached 748,047 which is 49.86% of Bahrain's population. As a result, focusing on the working sector alone will not be enough to represent the entire population of Bahrain. As a result, both working and non-working residents are defined. The selected sample for the study includes residents of Bahrain above the age of 20.

They were studied mostly during the weekend as that is when the participants are more convenient to take part.

### 3.2.1. Sectors of the labor force, organizations, industry, or groups from the sample are drawn:

The sample is drawn from all working residents of Bahrain.

### 3.2.2. Characteristics of the population sample:

The sample includes residents of multiple nationalities, housing typologies, and age groups working in different industries as well as those who are not working.

### 3.2.3. Strengths and limitations of the sample:

Strengths of the selected sample include being able to attain insight and data from people working in different industries, and living in different towns which gives a broader perspective of indoor air quality experienced by a wider variety of people that can represent the population than residents from a certain sector or those living in a certain community. Limitations of the sample include missing out on residents from specific areas and work backgrounds.

### 3.2.4. Justification for choosing such a sample:

By choosing residents across Bahrain, the study will not be confined to a particular industry or geographic area, thus being eligible to represent Bahrain's population. By segregating the workforce based on age groups (20-29, 30-39, 40-49, 50-59, 60 and above), a deeper analysis and conclusion is possible to be drawn in terms of satisfaction with indoor air for each group. Moreover, a working group of residents can easily compare and contrast their environmental qualities at home and workplace, thus making their responses more valuable compared to non-working residents who may not have experienced another environment for a long period to give a trustworthy overview. This is analyzed in the qualitative study where those residents who are working or studying can identify a clear difference in air quality between their homes and workplaces. In addition, by categorizing the sample into sub-groups in terms of their age, it is easier to identify those participants falling under ages 20-29 or 30-39 who suffer dissatisfaction due to variables like health and movement, which might otherwise be generalized to older participants. This helps to gain a deeper insight into evaluating that these issues affect the younger population as well to an extent that might otherwise be ignored.

### 3.2.5. Generalizing the population:

- Population Size: 1,700,000
- Sample Size: 400
- Confidence Level: 95%
- The margin of Error: 5%
- Total Surveys: 408
- Total Interviews: 46

## 3.3. The Sampling Technique

The sampling technique selected for this research is a Snowball Sampling Technique. Here the total population is divided into 2 major sub-groups, Working sector and the non-working sector. Further, each sub-group is categorized into their age groups (Table 2). In this study, the two types of segregation include working and non-working residents (qualitative study) and age-wise segregation of residents (quantitative study). The data collected by both these studies do not overlap and are clearly distinguished. Bahrain's total population as of 2020 includes 1,701,575 people of which 748,047 are working and 953,528 are non-working residents [24].

**Table 2.** Sampling

Qualitative Analysis (Interviews)				
Working Residents		Non-working Residents		
Quantitative Analysis (Questionnaire)				
Residents of Bahrain above 20 years				
20-29	30-39	40-49	50-59	Above 60

## 3.4. Data Collection Procedure

To collect the data, a combination of simple random sampling and convenient sampling was done as mentioned above. Primarily, the participants were selected from personal contacts. Further, through the help of personal contacts, several mutual contacts were selected to participate who are anonymous to the researcher. Thus, making it a Snowball Sampling technique. For the quantitative study, a questionnaire was sent across personal contacts and groups through social media which was further circulated through other contacts. For the qualitative study, both personal contacts and anonymous participants were included. The interviews were taken over phone calls as it was restricted to meet in person due to the pandemic. Further, by sharing contacts of mutual connection, several other participants were also interviewed by phone calls. The questionnaire was prepared and sent across. There were no requests involved in it. However, for the interviews, appointments were fixed over a week to schedule when each participant would be interviewed. Regarding the interviews, almost every person participated actively and engaged in the conversation.

The interview consisted of open-ended questions, which are listed as follows:

1. Are you productive when at home; Does the space give you a good spatial experience to stay productive in terms of working, studying, etc.?
2. Do you feel belonged/attached to your house? Does the space make you happy and comfortable?
3. Do you experience any health issues when indoors? (E.g., Allergies, Skin issues, Itchy eyes, etc.?)

4. Do other elements used at home contribute to affecting your health? (E.g., Cleaning products, cooking, the temperature of air conditioning, dust from furniture, etc.?)
5. Are you happy with the flexibility inside your house? Do you have enough space to move freely and comfortably?
6. Do you get sufficient day lighting and ventilation inside your house? Do you believe the incorporation of greenery inside and outside can help in better air quality and increased satisfaction?
7. Are you able to do your activities such as meditation/ exercise etc. comfortably whilst being indoors? Have you experienced the presence of polluted air in your house?
8. Overall, how satisfied are you with your indoor experience?
9. Do you consider these above-mentioned factors to contribute to your overall satisfaction? (Spatial experience, health, movement, etc.?)
10. During COVID-19, as you stayed more time indoors, did you experience any discomfort either from your house or from the neighbors? (E.g., Dust from furniture, the smell of paint, smoking, dust/smell from pets, etc.)

#### 4. Result-Qualitative Study

Through the process of coding/ indexing for the interviews collected, it was found that many participants experienced psychological issues and health issues whilst staying indoors for a long time in terms of air quality. In terms of spatial experience, participants responded that they did have a meaningful experience and a sense of place while being indoors. Most of the residents agreed that they were attached to their households. Thus, it is analyzed that IAQ does not affect an individual's spatial experience. No matter whether the place is polluted or not, residents are happy and satisfied if they are connected with other members in the comfort of their homes.

In terms of health factors, several residents were affected by health concerns such as asthma, dust allergies, headaches, and mental health issues. It was also found that other indoor factors affected user satisfaction with IAQ. Some of these include the usage of strong cleaning products at home, the smell of strong perfumes, dust during sandstorms, winter dust, and so on. Participants also reported that they felt suffocated whilst being indoors, especially during the COVID-19 lockdown. Moreover, products used for cleaning ovens caused headaches and burning sensations in the nose. Many participants suggested that lack of proper ventilation had negative effects on their overall well-being and described how with proper ventilation they can improve the quality of life. Moreover, the involvement of indoor and outdoor plants was found to be a great source of fresh air for the residents

and improved their satisfaction. However, this also had negative results as during the winter season, these plants invited flies and other insects, further causing a threat to their indoor air quality.

Internal factors also were found to have effects on IAQ in households. These included dust from furniture like tables, curtains, carpets, etc. When not cleaned regularly, the accumulation of dust on the furniture affected air quality. Moreover, the smell of cooking gases and pollution from the kitchen deeply affected residents' well-being. Having said that, many residents did not experience any of these issues from internal factors and were satisfied. In terms of behavioral patterns, participants expressed their interest in working from the workplace or outdoors than at home. This was prominent as they experienced a sense of place whilst at work and home, they were mostly attached emotionally which discouraged them from doing other activities. Moreover, residents found movement flexibility is restricted when at home which affected their satisfaction.

A connection between the selected variables and the main hypothesis of user satisfaction was derived. However, most participants did not find difficulty or restrictions in terms of behavioral patterns and their connection with IAQ. Meanwhile, aspects of health were found to be prominent factors that caused poor satisfaction with air quality in households. Moreover, it was found that irrespective of the levels of IAQ within the households, users were very much satisfied in terms of their spatial experience as a house contains emotional connection and comfort to the users as they are together with their family. In addition, it was found a majority of the participants reported they were satisfied and experienced no issues. However, most of them were actively engaged in sharing their experiences with indoor air quality and expressed their viewpoint about the variables and their interconnection to user satisfaction. All participants unanimously agreed that factors such as spatial experience, health, and behavioral factors directly affect satisfaction with indoor air quality.

Moreover, it was found that most of the participants encountered issues with ventilation as they lived in flats with no direct access to the outdoors or sufficient windows. This factor directly affects their overall satisfaction as they tend to feel suffocated, cramped, and congested. Yet another insight was the psychological impacts such spaces cause on users. In terms of productivity, both participants were productive when indoors as well as those who were unproductive. It was clearly stated initially by many that air quality did not play a role in affecting their productivity, though at a later stage, they stated they face issues like dust from sandstorms, poor air conditioning and a need to go out to get fresh air.

Air quality issues from cooking gases, meals, cleaning products, etc. were faced by many participants when given such examples. A comparative study between users' old house and new house experiences was very significant. It was found that due to poor air quality, the user experienced

headaches and dust from curtains and tables. It was found that the interviewee's mother and sister faced serious health issues like asthma and dust allergies. Due to issues such as lack of natural lighting and ventilation, poor infrastructure, smells, neighborhood, and poor air conditioning, the residents were forced to shift their houses to save the health of their families. In addition, many participants suggested the incorporation of green plants would improve the overall well-being and air quality indoors, especially as there's a lack of fresh air. Moreover, several participants expressed grief regarding their neighbors who burn trash and the smoke that is produced from it. Unfortunately, this has affected their overall air quality level experience. Skin allergies, suffocation, respiratory issues, psychological issues, and discomfort were some of the commonly used terms by various participants. This was indeed found through the process of coding.

## 5. Result-Quantitative Study

The survey consisted of 14 questions and 2 of them consisted of sub-questions. The questionnaire was organized in a very simple manner using simple sentences so that it was understood by every participant irrespective of their age and area of knowledge. As the questionnaire attempted to give multiple choices for most of the questions, participants were able to navigate and finish the survey easily as many hesitated to answer open-ended questions. However, there were options for extended answers for a couple of questions, for which some participants contributed to gain a good insight into their reasons. The age groups of participants were those above the age of 20. The total number of responses collected was 408, of which 33.6% were 20-29 years old, 20.6% were 30-39 years old, 17.2% were 40-49 years old, 18.4% 50-59 years old, and 8.6% were above the age of 60. Moreover, participants were also segregated based on whether they were working or non-working, of which 49.7% of the

participants were working and 50.3% were non-working residents of Bahrain (Figure 2).

Participants were asked if they were attached to their households initially, and this was asked to tackle their spatial qualities and experiences indoors. Significantly, 50.2% of the participants felt very much belonged to their houses, while 18.1% felt moderate and 31.6% did not feel belonged at all. To understand this further, they were asked to specify why they did not feel belonged and select from some of the given choices. It was drawn that 53.9% of the participants often were sick when indoors, while 36.2% felt there was a lack of proper lighting, and 19.6% voted there was a lack of natural lighting that contributed to their dissatisfaction with air quality. Moreover, 33.6% of the participants reported that dust played a vital role in affecting their air quality. (Figure 3).

Further, to analyze user productivity, it was derived that 58.7% of the participants were productive while working from their offices/workplace while 40.7% found it neutral irrespective of the location and others had a neutral approach. (Figure 4).

It could be analyzed that most of the participants preferred not to work or do their activities from their homes and reported that the space didn't encourage them to do so in terms of air quality, movement, and circulation patterns. Having said that, the reason behind not being productive indoors was analyzed and found to be mainly flexibility, as 53.6% of the participants voted so. In addition, 44.3% voted for lack of spaciousness indoors, 23.6% found it to be fresher and closer to greenery when outdoors and 23.2% reported that there was a better air conditioning system at their workplace. Meanwhile, there were several other inputs from the participants regarding what detached them from indoors. When asked about having a meaningful experience at home, 52.5% of the respondents voted that they do experience a meaningful spatial experience, of which 46.9% did not experience a spatial experience and others were not sure.

Are you currently working ?

0 / 344 correct responses

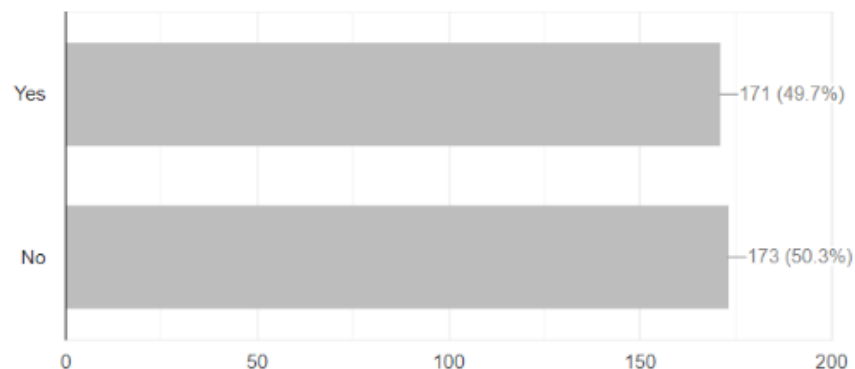


Figure 2. Survey Response on Working & Non-Working Participants



If not, could you specify what makes you detached from your house?

271 responses

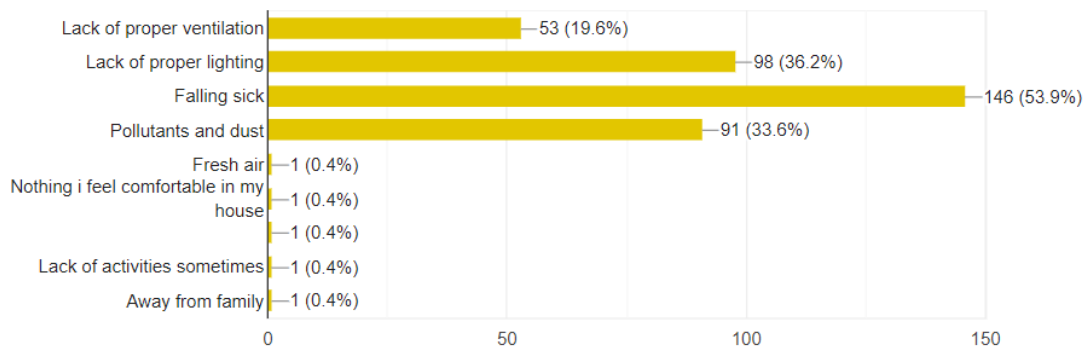


Figure 3. Participants’ responses on their reason for detachment from houses

Are you more productive while working from your house?

332 responses

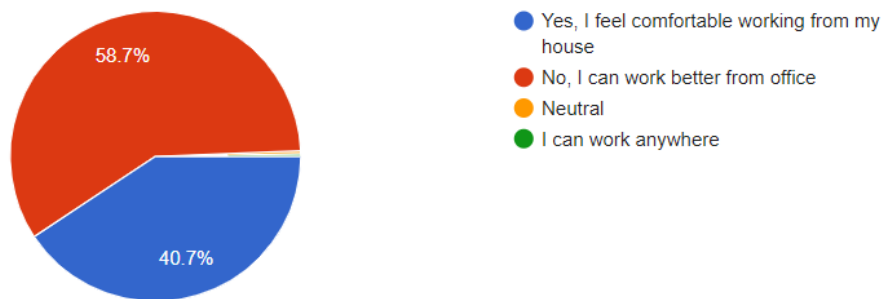


Figure 4. Participants’ responses on productivity while working from homes

Do you feel health is a factor contributing to your indoor comfort?

324 responses

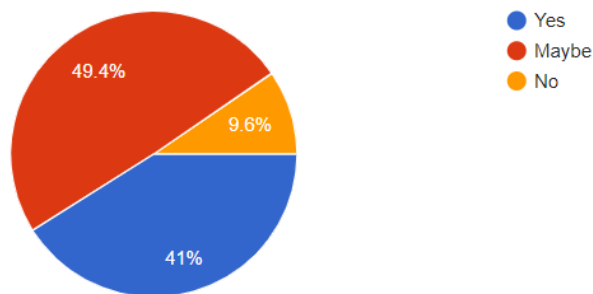


Figure 5. Participants' responses on Health as a Factor contributing to Indoor Comfort

Moreover, regarding the role of health in affecting user satisfaction; 41% of the respondents’ voted health does play a role in altering their satisfaction, while 49.4% were not sure and 9.6% disagreed. (Figure 5). In addition, when asked about the factors contributing to affecting overall

health while being indoors, 27.4% of respondents voted pollution from outdoors plays a role in affecting their health, while 35.5% voted dust from inside the room plays a role and 26.4% responded that allergies such as coughing, sneezing, sinus infections are important factors. Whereas

24.4% of the respondents agreed to have dryness and itchy eyes from indoor air. Moreover, 18.2% of the respondents blamed poor air conditioning for affecting air quality and overall health. Notably, 28% selected smoke and gas from the kitchen as the main factors contributing to health while 29% selected the usage of chemicals for cleaning as major threats. In addition, 23.5% voted for dust from carpets that affects health, 19.2% voted for insects, reptiles, and flies, and 22.8% voted for poor indoor water quality. However, only 16.6% voted for smoke from cigarettes as a health concern. (Figure 6).

Nevertheless, when asked about the factors that provide good air quality at home, 37.9% responded that keeping the house regularly cleaned can help in good air quality. Interestingly, 55.9% stated fresh air from outside can help in maintaining good air quality (Figure 6). Though 33.5% voted regular cleaning of AC can help, 48.1% said the inclusion of greenery can help. However, 20.8% also suggested inclusion of humidifiers can help maintain good air quality in homes. To analyze user behavioral patterns, it was asked if they were able to behave easily when at home. Surprisingly, 36.5% of users voted yes while 48% stated they could interact better when outside. Moreover, regarding movement patterns, 15.5% responded that they could move easily when outdoors. To understand users'

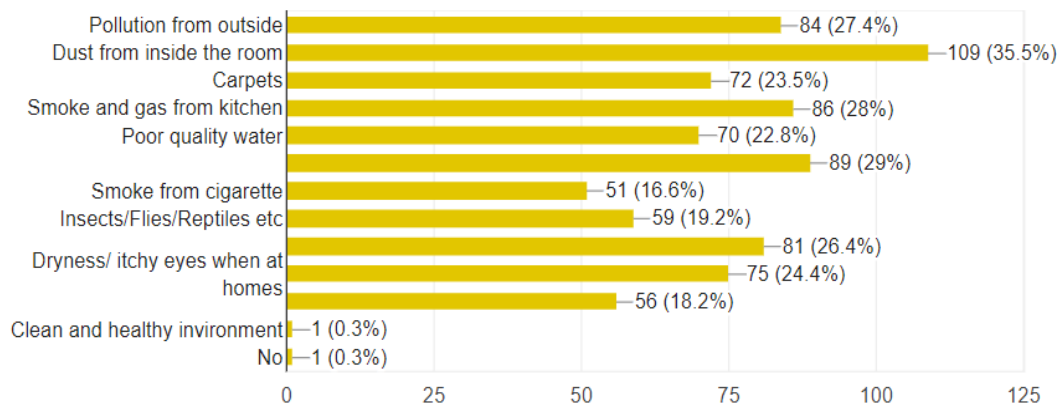
sensory experiences, a couple of questions were also additionally included. The first question was regarding the experience of disturbing noise from outdoors or nearby construction sites, of which 58.1% responded that it directly affects their mood while 41.9% stated the opposite. 70.8% responded that they sometimes do experience this disturbance, while 12.1% voted they always experience and 17.1% responded that they face such disturbance when they try to work. When asked if the foul smell from trash/chemicals affects the movement patterns inside the house, 25.3% stated that it affects them a lot while 55.2% experienced it somewhat but would try to stay away from such smell and 19.4% stated it does not affect them. When asked about the overall experience of poor indoor air quality, 39.8% of participants rarely experienced poor air, while 45.5% often experienced poor air and 14.7% always experienced poor indoor air (Figure 7).

User satisfaction with overall indoor air quality was tested on a scale of 1-5, where 5 is excellent and 1 is poor. It was found that:

- 11% voted a 5/5,
- 27.3% of respondents voted a 4/5,
- 39.3% voted a 3/5,
- 14.5% voted a 2/5 and
- 8% voted a 1/5

If yes, What factors contribute to affecting your health while at home? You can select more than one.

307 responses



**Figure 6.** Participants' responses on factors contributing to affect their health while at home

How often do you experience poor air inside the house?

319 responses

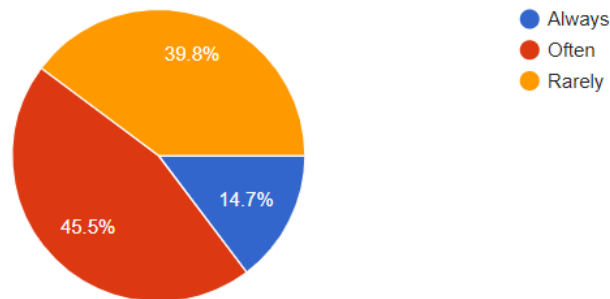


Figure 7. Participants response on how often they experience poor air

## 6. Discussion & Conclusions

All in all, the qualitative study was very insightful and helped to find out many possible reasons that contribute to user satisfaction with IAQ. Indoor factors and external factors equally contributed to affecting the indoor air quality. Moreover, the variables that were selected helped to create a connection with the main hypothesis of user satisfaction. However, only two of the selected variables were considered to be a successful choice as the third variable of user behavioral patterns didn't result in affecting user satisfaction with IAQ. It can be concluded that residents tend to compromise on the existing issues within their homes and tend to accept the way the air quality is and does not realize the importance of proper IAQ. A serious lack of awareness of the issue was found as many responded that they were satisfied despite having serious issues related to health, dust, and other internal factors. Most respondents believe these issues are not connected to the internal factors of IAQ of the built environment rather it is caused by external factors. Nevertheless, a good understanding of the issue of IAQ in households of Bahrain was gained and the need for proper maintenance of air quality levels indoors was found. Several families especially those who are working, could easily differentiate the levels of air quality in their workplace and their homes and stated that there was some sort of disturbance in their homes that contributed to their spatial experience and health: and finally, to their overall satisfaction.

With regard to the quantitative analysis through questionnaire, it is analyzed that most of the respondents voted for a neutral to a good experience of indoor air quality in general and most of them rarely experienced poor indoor air quality. Nevertheless, for the lesser population that faced issues with poor indoor air, some of the factors that contributed the most to their poor experiences were found to be health, allergies, poor air conditioning, dust, and pollution from indoors and

outdoors as well as the influence of cooking gas and pollution from the kitchen. Though the respondents initially expressed their positive response towards spatial experience, at a later stage, they also expressed sufferings from sensory experiences like poor smell and noise. An unexpected result drawn from the survey was the satisfaction of participants in terms of behavioral, movement, and interaction patterns. All in all, it can be concluded that the variables stated such as health and spatial experience do play a role in affecting user satisfaction. However, it is concluded that behavioral patterns are not contributing sufficiently towards user satisfaction and do not justify as a variable.

It can be concluded that most of the residents are generally satisfied with their experience of IAQ in households. Their satisfaction generally lies between neutral to good. Though most residents spent a larger amount of time in their respective houses during the pandemic, many did not face any difficulties. However, several residents mentioned psychological issues and mental health issues that they experienced whilst staying indoors. It is found that the major contribution is from lack of natural lighting and ventilation, and pollutants present indoors and that enter from outdoors during sandstorms, which affects resident's health, spatial experience, and movement patterns further altering their overall satisfaction. Though this has been studied widely both internationally and regionally, it is unfortunate that it has not been studied sufficiently in the context of Bahrain. Nevertheless, this research provides a detailed analysis of user satisfaction with IAQ among residents of Bahrain, and by segregating residents based on whether they were working or not, a broader analysis was made possible. However, there needs to be awareness among residents about the issues related to IAQ and the recommended PM levels for any country. It is indeed a cause of concern if users are not educated about the issue and as long as it is not controlled. If left untreated, it can cause a major threat to human health and overall well-being within the built

space, affecting them physically, emotionally, and mentally.

Altogether, it can be concluded that indoor air quality is a serious threat. All in all, the qualitative study resulted in a much more in-depth analysis and understanding of user experience of indoor air quality in households during COVID-19 in comparison to the quantitative analysis. In terms of the segregated groups of working and non-working, working residents preferred the air quality in their workplace to be cleaner and inviting and tended to spend more time outdoors than non-working residents. Thus, making it clear that there exist certain negative issues in the indoor environment, which need to be treated. Future research can study user satisfaction in areas other than households and identify the factors that contribute to IAQ in different spaces.

## Conflict of Interest

The author declares no conflict of interest.

## REFERENCES

- [1] Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Kafatygiotou, M., & El'sarrag, E, "Occupant productivity and office indoor environment quality: A review of the literature", *Building and environment*, vol. 105, pp. 369-389, 2016. <https://doi.org/10.1016/j.buildenv.2016.06.001> (<https://www.sciencedirect.com/science/article/abs/pii/S0360132316302001>)
- [2] Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Elsarrag, E., Mishra, S, "Occupant productivity and indoor environment quality: A case of GSAS", *International Journal of Sustainable Built Environment*, vol. 6, no. 2, pp. 476-490, 2017, ISSN 2212-6090, <https://doi.org/10.1016/j.ijbsbe.2017.11.001>. (<https://www.sciencedirect.com/science/article/pii/S2212609017302637>)
- [3] Seppanen, O., W. Fisk, M. Mendell, "Association of ventilation rates and CO<sub>2</sub> concentrations with health and other responses in commercial and institutional buildings", *Indoor Air* 9, vol. 4, pp. 226–252, 1999, DOI: 10.1111/j.1600-0668.1999.00003.x
- [4] Kumar P, Morawska. L., Martani. C., Biskos. G., Neophytou. M., Di Sabatino. S, Bell. M., Norford. L., Britter, R, "The rise of low-cost sensing for managing air pollution in cities", *Environ Int*; vol. 75, pp. 199–205. 2015, <https://doi.org/10.1016/j.envint.2014.11.019>.
- [5] Schieweck, A. et al., "Smart homes and the control of indoor air quality", *Renewable and Sustainable Energy Reviews*, 94, pp. 705–718, 2018, DOI: 10.1016/j.rser.2018.05.057.
- [6] Salthammer, T., Schieweck, A., Gu, J., Ameri, S., Uhde, E., "Future trends in ambient air pollution and climate in Germany – Implications for the indoor environment", *Building and Environment*, Vol. 143, pp. 661-670, 2018, <https://doi.org/10.1016/j.buildenv.2018.07.050>. (<https://www.sciencedirect.com/science/article/pii/S036013231830458X>)
- [7] Amoatey, P. et al., "Indoor air pollution and exposure assessment of the gulf cooperation council countries: A critical review", *Environment International*, 121, pp. 491–506, 2018, doi: 10.1016/j.envint.2018.09.043.
- [8] Földváry, V., Bekö, G., Langer, S., Arrhenius, K., & Petráš, D., "Effect of energy renovation on indoor air quality in multifamily residential buildings in Slovakia", *Building and Environment*, 122, pp. 363-372, 2017, <https://doi.org/10.1016/j.buildenv.2017.06.009>
- [9] Du, W. and Wang, G. "Indoor Air Pollution was Nonnegligible during COVID-19 Lockdown." *Aerosol and Air Quality Research*, vol. 20, 1851–1855, 2020, <https://doi.org/10.4209/aaqr.2020.06.0281>
- [10] Altomonte, S. et al. "Ten questions concerning well-being in the built environment", *Building and Environment*, 180, 106949, 2020, doi: 10.1016/j.buildenv.2020.106949.
- [11] Ortiz, M., Itard, L. and Bluysen, P.M., "Indoor Environmental Quality Related Risk Factors With Energy-Efficient Retrofitting Of Housing: A Literature Review", 2020, [online] Available at: <<http://creativecommons.org/licenses/by/4.0/>>
- [12] Albuainain, N., Sweis, G., Albalkhy, W., Sweis, R., & Lafhaj, Z, "Factors Affecting Occupants' Satisfaction in Governmental Buildings: The Case of the Kingdom of Bahrain", *Buildings*, vol. 11, no. 6, 231, 2021. <https://doi.org/10.3390/buildings11060231>
- [13] Tran, V. V., Park, D., & Lee, Y.-C, "Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality", *International Journal of Environmental Research and Public Health*, vol.17, no. 8, 2927, 2020. Retrieved from <http://dx.doi.org/10.3390/ijerph17082927>
- [14] Yang S. et al. "Energy, indoor air quality, occupant behavior, self-reported symptoms and satisfaction in energy-efficient dwellings in Switzerland", 171, 2020, Doi: 10.1016/j.buildenv.2019.106618.
- [15] Saha, J., Chouhan, P., "Indoor air pollution (IAP) and pre-existing morbidities among under-5 children in India : are risk factors of coronavirus disease" ( COVID-19 )", *Environmental Pollution*, 266, 115250, 2020, doi: 10.1016/j.envpol.2020.115250. <https://doi.org/10.1016/j.envpol.2020.115250>. (<https://www.sciencedirect.com/science/article/pii/S026974912033966X>)
- [16] Melikov,A, Kaczmarczyk,J, "Air movement and perceived air quality", *Build. Environ*. 47, 400–409, 2012, [http://refhub.elsevier.com/S0360-1323\(20\)30308-5/sref122](http://refhub.elsevier.com/S0360-1323(20)30308-5/sref122)
- [17] Fang,L., Wyon.D., Clausen.G., Fanger.P., "Impact of indoor air temperature and humidity in an office on perceived air quality", *SBS symptoms and performance*, *Indoor Air* 14, 74–81, 2004, [http://refhub.elsevier.com/S0360-1323\(20\)30308-5/sref80](http://refhub.elsevier.com/S0360-1323(20)30308-5/sref80)
- [18] Yao, W., Dal Porto, R., Gallagher, D.L., Dietrich, A.M., "Human exposure to particles at the air-water interface:

- Influence of water quality on indoor air quality from use of ultrasonic humidifiers”, *Environment International*, Volume 143, 2020, 105902, ISSN 0160-4120, <https://doi.org/10.1016/j.envint.2020.105902>. (<https://www.sciencedirect.com/science/article/pii/S0160412020318572>)
- [19] McGill, G., Qin, M. and Oyedele, L., “A Case Study Investigation Of Indoor Air Quality In UK Passivhaus Dwellings”, *Energy Procedia*, vol. 62, pp. 190 – 199 2014, <http://creativecommons.org/licenses/by-nc-nd/3.0/> doi: 10.1016/j.egypro.2014.12.380.
- [20] Alkadash, T.M., Alamarin, F., “An integrative conceptual framework on employee performance during COVID-19 pandemic for Bahrain SMEs”, *Psychology and Education*, vol. 58, no. 2, 3812-3817, 2021, [https://www.researchgate.net/profile/Tamer-M-Alkadash/publication/349462793\\_AN\\_INTEGRATIVE\\_CONCEPTUAL\\_FRAMEWORK\\_ON\\_EMPLOYEE\\_PERFORMANCE\\_DURING\\_COVID-19\\_PANDEMIC\\_FOR\\_BAHRAIN\\_SMEs/links/60311432a6fdcc37a83d9603/AN-INTEGRATIVE-CONCEPTUAL-FRAMEWORK-ON-EMPLOYEE-PERFORMANCE-DURING-COVID-19-PANDEMIC-FOR-BAHRAIN-SMEs.pdf](https://www.researchgate.net/profile/Tamer-M-Alkadash/publication/349462793_AN_INTEGRATIVE_CONCEPTUAL_FRAMEWORK_ON_EMPLOYEE_PERFORMANCE_DURING_COVID-19_PANDEMIC_FOR_BAHRAIN_SMEs/links/60311432a6fdcc37a83d9603/AN-INTEGRATIVE-CONCEPTUAL-FRAMEWORK-ON-EMPLOYEE-PERFORMANCE-DURING-COVID-19-PANDEMIC-FOR-BAHRAIN-SMEs.pdf)
- [21] UNESCO “COVID-19 Educational Disruption and Response”, 2020 cited in Alfiras, M., Bojjiah, J., Yassin, A.A., “COVID-19 Pandemic and the Changing Paradigms of Higher Education: A Gulf University Perspective”, *Asian EFL Journal*, vol.27, no. 5.1, 2020, [https://www.researchgate.net/profile/Amr-Yassin/publication/349380729\\_COVID-19\\_Pandemic\\_and\\_the\\_Changing\\_Paradigms\\_of\\_Higher\\_Education\\_A\\_Gulf\\_University\\_Perspective/links/602d95634585158939b065e7/COVID-19-Pandemic-and-the-Changing-Paradigms-of-Higher-Education-A-Gulf-University-Perspective.pdf](https://www.researchgate.net/profile/Amr-Yassin/publication/349380729_COVID-19_Pandemic_and_the_Changing_Paradigms_of_Higher_Education_A_Gulf_University_Perspective/links/602d95634585158939b065e7/COVID-19-Pandemic-and-the-Changing-Paradigms-of-Higher-Education-A-Gulf-University-Perspective.pdf)
- [22] Bahrain Air Quality Index (AQI) : Real-time air pollution level. Available at: <https://www.aqi.in/dashboard/bahrain> (Accessed: 13 August 2023).
- [23] Manama Air Quality index (AQI) and Bahrain Air Pollution (no date) IQAir. Available at: <https://www.iqair.com/bahrain/capital-governorate/manama> (Accessed: 14 August 2023).
- [24] Worldometers.info. 2020. Bahrain Population (2020) - Worldometer. [online] Available at: <<https://www.worldometers.info/world-population/bahrain-population/>>