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Assessing the Impact of Indoor Environmental Quality on Occupant Well-being in Bahrain's Hospitals

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Abstract

The quality of the indoor environment has substantial impacts on occupant well-being and quality of life. Maintaining a positive indoor environment is particularly critical in complex architectural environments such as healthcare facilities. This paper adopts a mixed methodological approach to assess occupant well-being through architectural design and indoor environmental quality in one of Bahrain's private hospitals. A total of 54 hospital occupants participated in an online questionnaire to understand their perception of the indoor environment quality and its impact on their well-being. On-site observations are conducted to analyze the current physical state of the hospital from an architectural point of view, and triangulate the results with the questionnaire results. The findings shed light on the importance of outdoor views and thermal comfort in enhancing occupant well-being. The results provide valuable insights to designers and stakeholders to improve the quality of life in hospitals in Bahrain, through design considerations related to the indoor environmental quality.

Keywords: well-being; quality of life; sustainable healthcare; indoor environmental quality.

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1. Introduction

1.1 Background and Context

The relationship between indoor environmental quality (IEQ) and well-being is a complicated and significant area of study (Al-Horr et al., 2016). Various thermal, acoustic, visual, and chemical factors can impact the well-being of occupants in indoor spaces, both short-term and long-term (Deng et al., 2024). Human beings spend approximately 80-90% of their time indoors. Therefore, a lot of energy is spent to ensure the indoor environment meets adequate conditions that accommodate the requirements of occupants (Dimitroulopoulou et al., 2023). The global climate crisis and the increase in greenhouse gas emissions have a direct effect on the quality of life, affecting human well-being from different aspects. This emphasizes the urgency of designing sustainable, healthy buildings with positive indoor environments to mitigate and adapt to the adverse effects of climate change (Zhang et al., 2024). The United Nation's Agenda for Sustainable Development explicitly highlights the importance of this through the Sustainable Development Goals. Goal 3 in particular focuses on Good Health and Well-being, which looks at "ensuring healthy lives and promoting well-being for all at all ages".

Various studies explored different dimensions of the relationship between IEQ, well-being, and the quality of life. Al-Horr et al. (2016) and Wu et al. (2023) explored the direct relationships between IEQ, well-being and comfort. Niza et al. (2023) examined the link between IEQ and the SDGs. Mujan

et al. (2019) assessed the influence of IEQ on human health and productivity. Human health directly depends on the quality of the indoor environment, emphasizing its significance, particularly in healthcare buildings (Silva, et al., 2023). Numerous studies confirm the role of IEQ in improving healthcare environments (Shen, et al., 2023). A recent systematic literature review investigating IEQ in healthcare facilities places the United States as the top geographic location in relation to the number of articles published on the subject. Saudi Arabia is the only Gulf Cooperation Council (GCC) country with a publication in the subject, stressing the limited research in the region (Ackley et al., 2024).

1.2 Problem Statement and Research Gap

Bahrain is an archipelago of approximately 40 islands, located in the Arabian Gulf (Afzal et al., 2022). Its greenhouse gas emissions per capita are amongst the highest in the world (Alsabbagh & Alnaser, 2023). According to the Mercer Quality of Living City Ranking, Manama, the capital of Bahrain ranks the 144th out of a total of 241 cities. Out of the six GCC countries, Bahrain is ranked the second to last for the quality of life. Despite this, the government of Bahrain has presented continuous sustainability efforts to mitigate climate change, achieve carbon neutrality, and enhance the well-being and quality of life of residents (Alsabbagh & Alnaser, 2022). The National Economic Vision 2030, Government Plan, and National Health Plan underline the importance of improving the quality of life in Bahrain, in line with the national and global sustainability goals. The main research problem relates to the increase in greenhouse gas emissions in Bahrain and the decline in the quality of life. The gap of limited research on sustainable healthcare and IEQ in Bahrain healthcare settings drives the need for studying the complex environments of hospitals. This building typology consumes the highest energy, yet has the potential to significantly contribute to the betterment of human well-being and environmental health.

1.3 Objectives and Hypotheses

Within this context, the aim of the research addresses the local knowledge gap on sustainable healthcare in the region and seeks to assess the impact of IEQ on the well-being of occupants within a private hospital in Bahrain. The research question is thus formulated as “What is the impact of the IEQ on the well-being of occupants within the selected hospital in Bahrain?”. The objectives of the study are as follows: 1) investigating occupant perceptions of well-being and the IEQ, 2) analyzing the current physical state of the hospital, and 3) assessing the impact of IEQ on well-being. The research hypothesis is as follows: There is a significant relationship between IEQ and the perceived well-being of hospital occupants. The research adopts a mixed methodology approach consisting of a quantitative questionnaire and qualitative observations. The questionnaire is used to achieve the first objective of investigating perceptions, whilst the observations target the second objective to analyze the state of the hospital. The findings are triangulated and statistically analyzed through correlation analysis to assess the impact of IEQ on the well-being of occupants. The results guide the proposal of recommendations to enhance the well-being and quality of life of occupants in the hospital.

1.4 Significance and Structure of the Paper

This paper is structured in five sections. The first section presents an extensive literature review on IEQ and its impact on well-being, the methods used for assessing IEQ, and its considerations in the context of hospitals in Bahrain. The detailed methodology is explained in the materials and methods section, followed by the results, discussion, and conclusion highlighting recommendations for enhancing the well-being of hospital occupants in Bahrain. Figure 1 illustrates the structure of the paper in detail. This work adds to the body of knowledge on sustainable healthcare by investigating the impact of IEQ on well-being. Additionally, it addresses the knowledge gap of limited research on sustainable healthcare in Bahrain and in the GCC, and particularly on IEQ within the healthcare setting.

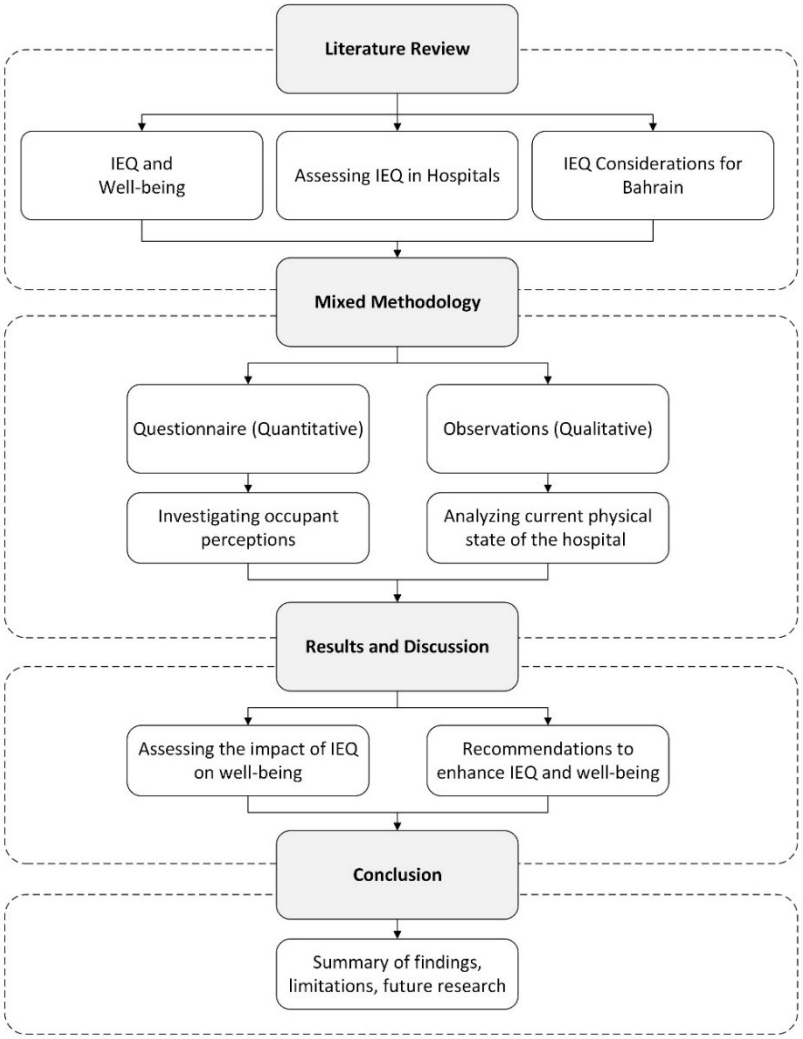

Figure 1. Structure of the Study (Developed by Authors).

2. Literature Review

2.1 Understanding Indoor Environmental Quality and Its Impact on Well-being

The IEQ refers to the overall quality of conditions that affect the health, well-being, comfort, and productivity of occupants, and is considered one of the most important parameters in building design (Mujan et al., 2019). Zhang et al. add that it also has an impact on the cognitive performance and satisfaction of occupants (Zhang et al., 2023). The U.S Green Building Council share that addressing IEQ can improve the quality of life, reduce stress and injuries, increase resale values of buildings, and reduce liability for owners. The significance of IEQ and nature in reducing stress and enhancing well-being is also theoretically supported in Ulrich's Theory of Supportive Design and Kaplan's Attention Restoration Theory. These fundamental theories have become increasingly popular in supporting well-being architecture and healing environments. The IEQ is an integral aspect in sustainable and green building design, and is essentially characterized by four categories, which are thermal comfort, air quality, lighting, and acoustics (Khovalyg et al., 2020). Thermal comfort includes maintaining a comfortable temperature, humidity and ventilation levels to avoid health related issues such as dehydration and irritations. Air quality addresses the pollutants in the air to reduce contaminants, and maintain optimal oxygen levels. A study by the American College of Allergies shows that polluted indoor air is the cause of 50% of all illnesses. The term sick building syndrome has also been coined to describe a range of health-related and discomfort symptoms caused by poor IEQ which are

experienced by building occupants (Kubba, 2017). Lighting is often described based on its impact on visual performance, intimately effecting behaviour and aesthetics, whilst supporting social interactions (Allan et al., 2019). Acoustical performance is another integral aspect of the indoor environment, and particularly in hospitals as noise levels in hospital environments have been increasing during the last 70 years, impacting the stress levels and well-being of hospital occupants (Lam et al., 2022).

Emerging research on IEQ shows an increasing number of papers on design-based optimization to enhance all aspects of the indoor environment whilst reducing building energy consumption, in addition to papers on improving comfort and the well-being of occupants through design guidelines and the integration of technology (Wu et al., 2023). Fantozzi and Rocca (2020) summarize and link the main categories of IEQ with aspects related to human comfort and risks to human health in Figure 2. The American Society of Heating, Refrigerating, and Air Conditioning Engineering (ASHRAE) suggests that not only is it necessary for all categories of the indoor environment to reach satisfactory levels, but also to limit the adverse impacts between them. Following this general discussion on the significance of the IEQ on well-being, the next section of this literature review discusses methods of assessing the indoor environmental quality in the context of hospitals.

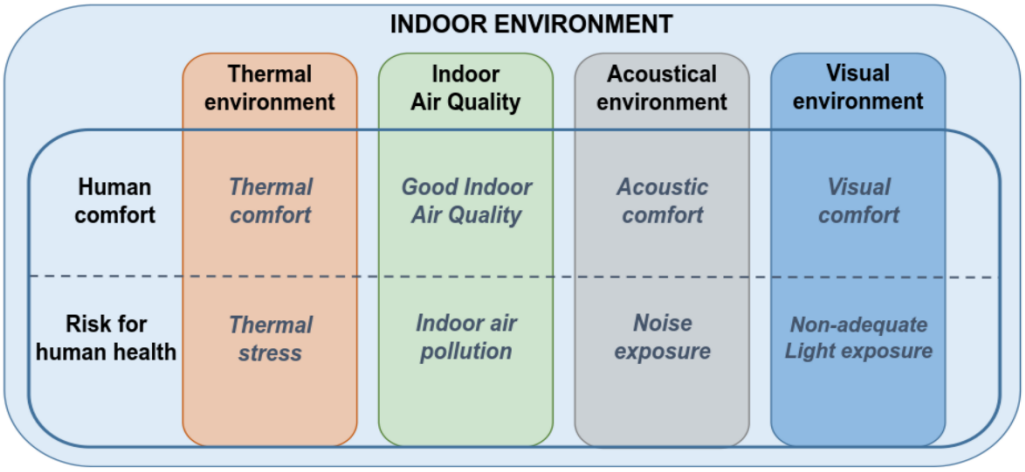

Figure 2. Fantozzi and Rocca's (2020) links between IEQ categories, human comfort, and risk for human health.

2.2 Assessing Indoor Environmental Quality and Well-being in Hospitals

The IEQ of healthcare buildings is a complex concept which requires special efforts to protect occupants against diseases, ensure infection control, speed up patient recovery, and improve staff performance and well-being. This idea goes back to Ulrich's Theory of Supportive Design which sheds light on how the physical environment within a healthcare setting plays an important role in reducing patients' stress levels and promoting satisfaction and recovery. This is achieved through physical elements supporting perceived control, positive distractions such as outdoor views and nature, and social support (Andrade et al., 2017). This is in line with Kaplan's Attention Restorative Theory which emphasizes the importance of nature in facilitating restoration and alleviating cognitive fatigue. Architectural advancements today reflect the significance of these environment-behaviour theories and are paving the way for more human-centered hospital environments (Liu et al., 2024b), focusing on enhancing the well-being of occupants through the indoor environment (Manca et al., 2023).

In a systematic literature review on IEQ in healthcare facilities, Ackley et al. (2024) summarize the categories and provide recommendations for enhancing the indoor environment through architectural design, as outlined in Table 1.The first category of the IEQ, namely the thermal comfort category exhibits significant variability in healthcare buildings. Healthcare buildings are primarily designed based on medical requirements, with minimal consideration to the thermal comfort (Yuan et al., 2022).

The thermal comfort in these buildings is heavily influenced by the health conditions of individuals, seasonal variations, the level of physical activity, age, gender, and the time of day. Additionally, there are usually significant differences between the levels of comfort of patients and staff, as patients prefer warmer temperatures in comparison to the healthcare staff (Ackley et al., 2024). Researchers and experts have developed various models to assess thermal comfort, because of its significant contribution to the overall IEQ. Fanger's classical PMV model combines six parameters to assess thermal comfort. Four of the six parameters are related to the physical environment, highlighting its significance, which include air temperature, radiation temperature, humidity, wind speed, and two of which are related to the users of the space, which are clothing thermal resistance and human activity (Zhao et al., 2021). The indoor air quality of hospitals directly affects occupant satisfaction, recovery, well-being, and rates of infection (Shajahan et al., 2018). Adequate ventilation, including controlled CO2 levels, humidity, and temperature is key to ensuring an acceptable air quality in hospital buildings. This can be achieved through continuous monitoring of the indoor air quality, integration of openable windows and efficient HVAC systems, and the extraction of contaminated air through extraction systems (Ackley et al., 2024; Ha et al., 2022; Silva, et al., 2023). Acoustics, or noise levels also play a vital role in ensuring the safety and comfort of hospital occupants.

The sources of noise levels in healthcare buildings include peoples' conversations and the noise of medical and building equipment. High levels of noise can effect patient outcomes, satisfaction levels, safety, and recovery, therefore it is critical to maintain adequate levels of noise throughout the entire hospital building (Greenfield et al., 2020). Design recommendations for a healthy acoustical environment in hospitals include ensuring the flexibility of opening and closing doors, utilizing absorbent materials and furniture, and promoting quietness through signages and written instructions (Church, 2020). The final IEQ category is associated with visual comfort, and mostly daylighting. Hospitals require balanced levels of daylighting to aid in the recovery and well-being of occupants, without causing discomfort from glare and excessive daylighting. This category also highlights the importance of outdoor views and views of nature, aligned with Ulrich's Theory of Supportive Design, and Kaplan's Attention Restorative Theory. This can be achieved through maximizing window sizes, having a good building orientation, the use of flexible shading and materials with reflective properties and colour.

Table 1. Ackley et al.'s (2024) recommendations for enhancing the indoor environmental quality in healthcare buildings, based on a systematic review of literature.

IEQ Parameter	Thermal Comfort	Air Quality	Acoustics	Visual Comfort
Design Recommendations	● Temperature between 21-24 °C ● Good building orientation/shading for solar control ● Appropriate materials to mitigate temperature variation ● Good wall, floor, roof insulation	● CO_2 level < 800 ppm ● Openable windows ● Adequate mixed ventilation techniques	● Noise level < 45 dB(A) ● Flexibility to open and close doors and windows ● Absorbent materials ● Signages and instructions to reduce noise	● Maximize window size ● Good building orientation ● Flexible shading to prevent glare ● Material colour and reflectance

Several standards and benchmarks have been established over the past 20 years to guide the design of adequate indoor environments. These include the WELL Building Standard v2, LEED v5, and ASHRAE Standards (Niza et al., 2023). Ackley et al.'s recommendations are in line with these standards and therefore they have been adopted in this study, to be used as a guide and checklist for the observational studies. Additionally, many methodologies are utilized to assess the IEQ of

buildings. These include objective experimental measures using measurement devices and monitoring during site observations, and subjective methods such as questionnaires to assess perceptions of the environment and well-being (Ackley et al., 2024). Both qualitative and quantitative methods are adopted in this study, which will be discussed in the materials and methods section. This section presented an overview of indoor environmental quality in the context of healthcare buildings, and the following section will delve into a background on Bahrain the local IEQ considerations to set the scene for the research.

2.3 Indoor Environmental Quality Considerations for Bahrain

Bahrain is considered as a hot, humid island in the Arabian Gulf with long summers and dry winters (Elghonaimy & Mohammed, 2019). Due to the intensity of the climate, residents spend most of their time indoors during most months of the year, emphasizing the importance of the indoor environment. Existing literature confirms that indoor air pollution is a considerable threat to human health in the GCC countries due to the high exposure to indoor air pollutants, poor ventilation, the burning of biomasses, and overcrowding (Amoatey et al., 2018). The newly established Green Building Manual briefly touches upon some of the IEQ attributes in the design of new buildings in Bahrain, however it does not explicitly address them fully.

The Government of Bahrain has also introduced its new tourism strategy which presents medical tourism as a fundamental pillar to enhance the tourism in Bahrain. This addresses the importance of enhancing the well-being and quality of life within healthcare environments as a strategy to boost tourism. That being said, the National Health Regulatory Authority's guide for the design of medical facilities does not explicitly address well-being or the IEQ in its entirety. This highlights the need for clear policies and design guidelines for healthcare buildings that clearly address the indoor environment and the well-being of occupants to achieve the country's national sustainability and tourism goals and enhance the quality of life. There is a limited number of published articles exploring the IEQ in healthcare buildings in Bahrain. Although Albuainain et al. (2021) examined the IEQ factors that affect occupant satisfaction in Bahraini governmental buildings, there are currently no studies addressing the indoor environment of hospitals in Bahrain. This underscores the importance of this study and the need for this research which aims to assess the impact of the IEQ on occupant well-being in Bahrain's hospitals.

3. Materials and Methods

3.1 Study Design and Setting

This research adopts a mixed methodology to address the research question and objectives and assess the impact of the indoor environment on well-being. The detailed structure of the methodology is depicted in Figure 3. A quantitative questionnaire is used to investigate occupant perceptions of well-being and the indoor environment. It is considered a fundamental data collection method in studies involving occupant comfort and satisfaction (Albuainain et al., 2021). The following four parameters evident in literature are used to investigate the IEQ: thermal comfort, air quality, acoustics, and visual quality. The sampling criteria ensured having a balanced representation of different types of hospital staff for more comprehensive results. Site observations are also conducted to analyse the current physical state of the hospital and triangulate the results. Hospitals are the most energy intensive building typologies within the healthcare sector, and are adopted in this study. Currently, there are 3 licensed government hospitals and 22 licensed private hospitals in Bahrain. One of the leading private hospitals has been selected as the case study for this research due to its strategic location in the Capital Governorate, increased number of patients (approximately 80,000 visits per year), and accessibility for the data collection. The hospital's location within the map of Bahrain is illustrated in Figure 4. This study sets the foundation for a research project involving multiple hospitals in Bahrain.

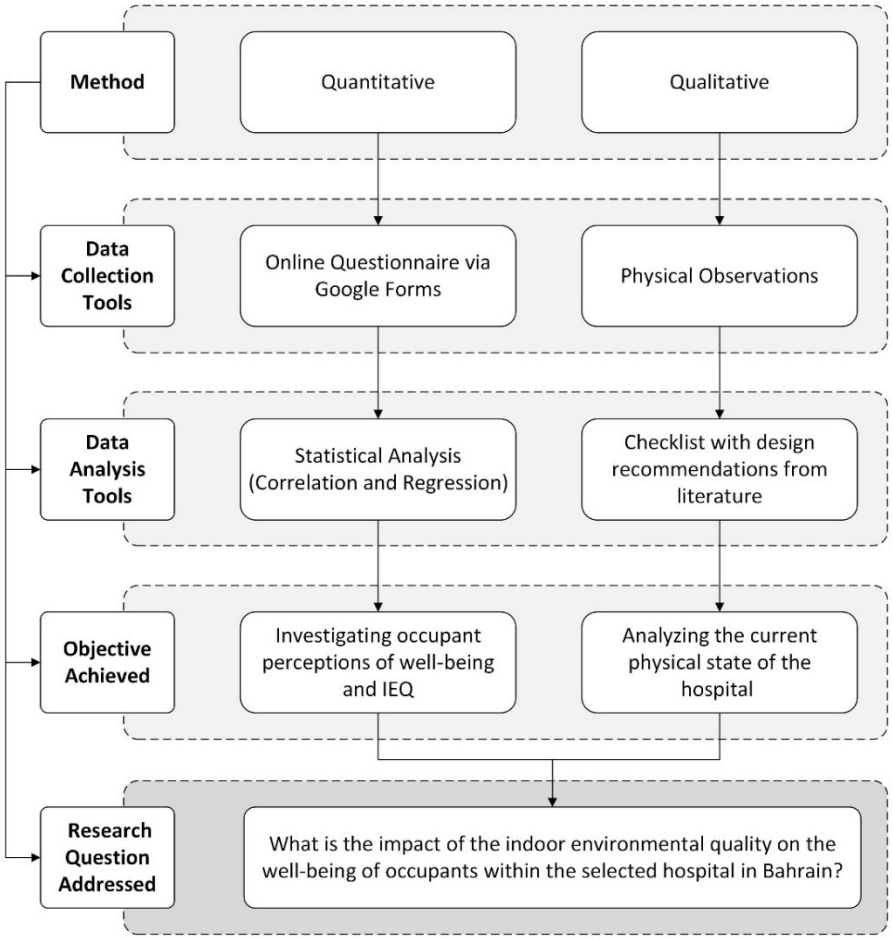

Figure 3. Structure of the mixed-methodological process illustrating links between research and tools and how they address the objectives and primary research question.

Figure 4. Location of the selected hospital for the research, centrally located within the Capital of Bahrain.

3.2 Questionnaire

To investigate the perceptions of occupants regarding their well-being and the IEQ of the hospital environment, an online questionnaire was administered via Google Forms during the month of November, 2024. A total of 54 individuals participated in the study, and Table 2 presents the demographics of the participants in detail. While convenience sampling may introduce a degree of selection bias, the sample included a diversity of participants and still offers valuable insights on IEQ perceptions. The most important inclusion criteria for the participants was that they are occupants of the hospital, including nurses, doctors, administrative staff, and support staff. Visitors and patients were excluded from this questionnaire, as their perceptions of the environment might be affected by other factors such as their physical and mental conditions. A formal letter was sent by the research team to hospital management to gain the ethical approvals prior to the distribution of the questionnaire. The questionnaire was then distributed to the employees of the hospital through the hospital administration, including the aim of the study and an explanation informing the participants of the confidentiality and anonymity of their data, which would be used solely for research purposes.

The design of the questionnaire was based on the literature, and included a demographic section asking participants about their role at the hospital, the years of service, and their perception of their overall comfort and well-being. This section included a question asking them about their experience of any physical symptoms which may be related to the quality of the indoor environment, and their awareness of any energy efficiency measures in the hospital. The second section included Likert-scale questions to assess their perception of the indoor environment, and of the architectural factors that impact their well-being. The authors are aware of the potential bias due to the subjective nature of the questions, therefore site observations have also been included to triangulate the results and mitigate bias. The questionnaire data was subjected to statistical analysis on Microsoft Excel to analyze the findings. The frequency of the distributions summarizes the results for each of the categorical variables related to the demographics. Exploratory correlation analysis was adopted to investigate which indoor environmental quality variables are strongly associated with the overall perception of well-being, while regression analysis was used to identify which architectural factors impact well-being the most. While Likert-scale data is technically ordinal, it is common practice in social sciences and health research to treat them as interval-level data. The following part discusses the site observations.

Table 2. Demographics of the questionnaire participants.

Variable	Category	n	%
Role at the hospital	Nurse	22	40
	Doctor	8	15
	Administrative Staff	15	28
	Support Staff	9	17
Years of service at the hospital	< 1 year	5	9
	1-3 years	14	26
	3-5 years	29	54
	5+ years	6	11
Rate your overall physical comfort and well-being in the hospital	1-Very uncomfortable	1	2
	2-Uncomfortable	11	20
	3-Neutral	7	13
	4-Comfortable	31	58
	5-Very comfortable	4	7
Frequency of experiencing physical symptoms (fatigue, headaches, eye strain) that may be related to the indoor environment	1-Never	1	2
	2-Rarely	10	19
	3-Sometimes	26	48
	4-Often	13	24
	5-Always	4	7
Awareness of energy efficiency measures in the hospital	Renewable Energy Sources	0	0
	Motion-censored Lighting	0	0
	Dual flush toilets	0	0
	Staff training on Sustainability	35	65
	Not Aware	19	35

3.3 Observations

The research team conducted site observations to analyze the current state of the hospital and triangulate the results with the findings from the questionnaire. Ackley et al.'s design recommendations to improve the IEQ were used as a guidelines and checklist during the site observations, as they combine different sources from literature in line with the WELL Building Standard and the LEED credits for the IEQ category. A site visit was conducted by the research team in November 2024 after obtaining permission from the hospital management, to determine the presence of Ackley et al.'s recommended architectural factors and indicators related to the indoor environment, which are outlined in Table 3.

Table 3. Checklist used to determine the presence of architectural factors related to the indoor environment.

IEQ Parameter	Indicator
Thermal Comfort	Temperature between 21-24 °C
	Good building orientation/shading for solar control
	Appropriate materials to mitigate temperature variation
	Good wall, floor, roof insulation
	Openable windows
	Adequate mixed ventilation techniques
Acoustics	Noise level < 45 dB(A)
	Flexibility to open and close doors and windows
	Absorbent materials
	Signages and instructions to reduce noise
Visual Comfort	Maximized window size
	Good building orientation
	Flexible shading to prevent glare
	Material colour and reflectance

Ethical permissions were also obtained for photography purposes. Due to the unavailability of instruments to measure CO_2 levels, the variable was omitted from the IEQ observation checklist.

4. Results

4.1 Questionnaire

A total of 54 hospital occupants participated in the study, of which 40% were nurses, 15% were doctors, 28% were administrative staff, and 17% were support staff including maintenance and cleaning. The majority (54%) of participants claimed to have been working at the hospital for the duration of 3-5 years, whilst 26% of them have worked for 1-3 years, 11% have worked for more than five years, and only 9% have been working for less than a year. When the participants were asked to rate their overall physical comfort and well-being at the hospital, a large 58% voted for comfortable, 20% were uncomfortable, 13% were neutral, 7% were very uncomfortable, and 2% claimed to be very uncomfortable at the hospital. Most of the participants (48%) said that they 'sometimes' experience physical symptoms such as fatigue, headaches, and eye strains which may be related to the indoor environmental quality. 24% of the participants said that they experienced these symptoms often, 19% rarely experience any symptoms, 7% of them always experience some sort of symptom, and 2% of them never experience any symptoms at all. Regarding the awareness of energy efficiency measures in the hospital, most of the occupants (65%) stated that they were aware of staff training on sustainability at the hospital, whilst the other 19% were not aware of any initiatives. No participants reported the presence of renewable energy sources, motion-censored lighting, or dual flush toilets at the hospital. The participants were asked to rate four environmental quality factors in the hospital based on their personal perspectives, which are outlined in Table 4.

Table 4. Checklist used to determine the presence of architectural factors related to the indoor environment.

	Variable	Category	n	%	Mean	SD
Rate the following indoor environmental quality factors in the hospital	Air quality (ventilation/smells)	1-Very poor	0	0	4.31	0.47
		2-Poor	0	0		
		3-Fair	0	0		
		4-Good	37	69		
		5-Excellent	17	31		
	Thermal Comfort (temperature control)	1-Very poor	0	0	4.00	0.64
		2-Poor	2	4		
		3-Fair	5	9		
		4-Good	38	70		
		5-Excellent	9	17		
	Visual Comfort (daylight/artificial lights)	1-Very poor	0	0	3.63	0.78
		2-Poor	6	11		
		3-Fair	12	22		
		4-Good	32	59		
		5-Excellent	4	8		
	Noise	1-Very poor	0	0	3.85	0.56
		2-Poor	2	3		
		3-Fair	7	13		
		4-Good	42	78		
		5-Excellent	3	6		

On average, the air quality which includes ventilation and smells had the highest mean of 4.31, and was rated as ‘good’ by 69% of the participants and ‘excellent’ by 31%. The temperature control had a mean of 4 and was mostly rated as ‘good’ by 70% of the participants, and poor by only 4%. As for the quality of the daylighting and artificial lighting, the mean was 3.63, and 59% of the participants gave a ‘good’ rating, while 11% gave a ‘poor’ rating. Moreover, the majority claimed that the noise at the hospital were ‘good’ (78%), while some believed they were ‘poor’ (3%). The comparison between the means of the four indoor environmental quality variables is visually depicted in Figure 5.

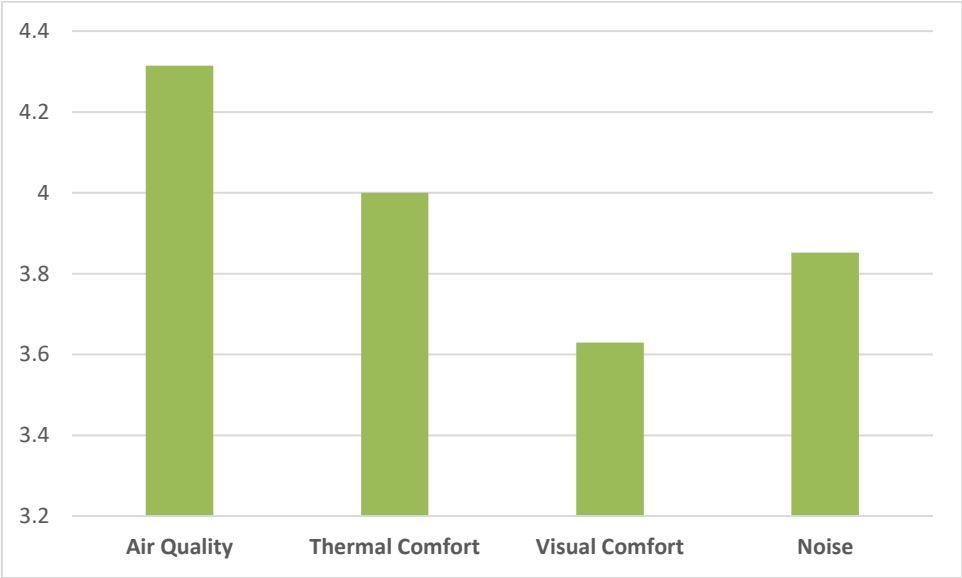

Figure 5. Comparison of means across the four indoor environmental quality variables.

The participants of the study were also asked to rate how specific architectural factors in the hospital impact their well-being. The consensus from the results highlights that natural light extremely affects the well-being of 55% of the participants; outdoor views extremely affect 46% of the participants, quiet spaces and the building layout extremely affect 54% of the participants. As for the proximity to restrooms, it extremely affects 59% or participants, while indoor plants extremely affect 52%. The temperature control extremely affects 63%, the noise 56%, and the accessibility and circulation within the building 61%. The indoor plants was the only factor that had some kind of impact on all of the participants of the study. Table 5 presents the percentages of these results in more detail.

Table 5. Assessing the impact of architectural factors on the well-being of hospital occupants.

Variable		Category	n	%	Mean	SD
Rate how the following architectural factors in the hospital impact your well-being	Natural Light	1-Not at all	1	2	4.44	0.79
		2-Slightly	1	2		
		3-Moderately	1	2		
		4-Very much	21	39		
		5-Extremely	30	55		
	Outdoor Views	1-Not at all	1	2	4.11	1.06
		2-Slightly	5	9		
		3-Moderately	6	11		
		4-Very much	17	32		
		5-Extremely	25	46		
	Quiet Spaces	1-Not at all	2	3	4.04	1.23
		2-Slightly	6	11		
		3-Moderately	9	17		
		4-Very much	8	15		
		5-Extremely	29	54		
	Building Layout	1-Not at all	2	3	4.00	1.26
		2-Slightly	7	13		
		3-Moderately	9	17		
		4-Very much	7	13		
		5-Extremely	29	54		
	Proximity to Restrooms	1-Not at all	2	4	4.09	1.26
		2-Slightly	7	13		
		3-Moderately	7	13		
		4-Very much	6	11		
		5-Extremely	32	59		
	Indoor Plants	1-Not at all	0	0	4.17	1.02
		2-Slightly	5	9		
		3-Moderately	9	17		
		4-Very much	12	22		
		5-Extremely	28	52		
	Temperature/Ventilation	1-Not at all	2	3	4.43	0.96
		2-Slightly	1	2		
		3-Moderately	3	6		
		4-Very much	14	26		
		5-Extremely	34	63		
	Noise Control	1-Not at all	2	3	4.28	1.02
		2-Slightly	1	2		
		3-Moderately	7	13		
		4-Very much	14	26		
		5-Extremely	30	56		
	Accessibility/Circulation	1-Not at all	2	4	4.33	1.05
		2-Slightly	2	4		
		3-Moderately	5	9		
		4-Very much	12	22		
		5-Extremely	33	61		

Considering the non-normality of the questionnaire data, and the nature of the Likert-scale ordinal data, the Spearman Correlation was used to analyze the correlation between the well-being scores of the participants and the indoor environmental variables and architectural factors. The data was ranked

prior to conducting the correlation, and the correlation coefficients are displayed in Table 6. Additionally, a multiple linear regression was conducted to assess the impact of the variables on well-being. The results indicate that all the architectural factors in the hospital significantly have an impact on well-being, except for the natural light and temperature control.

Table 6. Spearman Correlation analyzing the correlation between different variables and the well-being of participants.

Variable	Spearman Correlation Coefficient	*p*-Value
Indoor Environmental Quality Variables		
Air Quality	0.24	0.807
Thermal Comfort	0.55	0.006
Visual Comfort	0.36	0.012
Noise	0.43	0.011
Architectural Factors		
Natural Light	0.24	0.008
Outdoor Views	0.57	0.000
Quiet Spaces for Breaks	0.50	0.000
Building Layout	0.46	0.000
Proximity to Restrooms	0.49	0.000
Indoor Plants and Greenery	0.43	0.000
Temperature Control and Ventilation	0.38	0.002
Noise Control	0.46	0.000
Accessibility and Circulation	0.47	0.000

The correlation results indicate that outdoor views and thermal comfort have the highest positive correlations with the well-being of participants. Surprisingly, the results highlight that natural light has the least correlation with well-being. Although natural light was the most IEQ factor affecting well-being, the statistical analysis revealed a weaker correlation with the well-being score. This suggests a possible gap between perceived importance and measurable impact due to the limited variation in responses, or the influence of other variables. The comparison between the spearman correlation coefficients for each variable is presented in Figure 6.

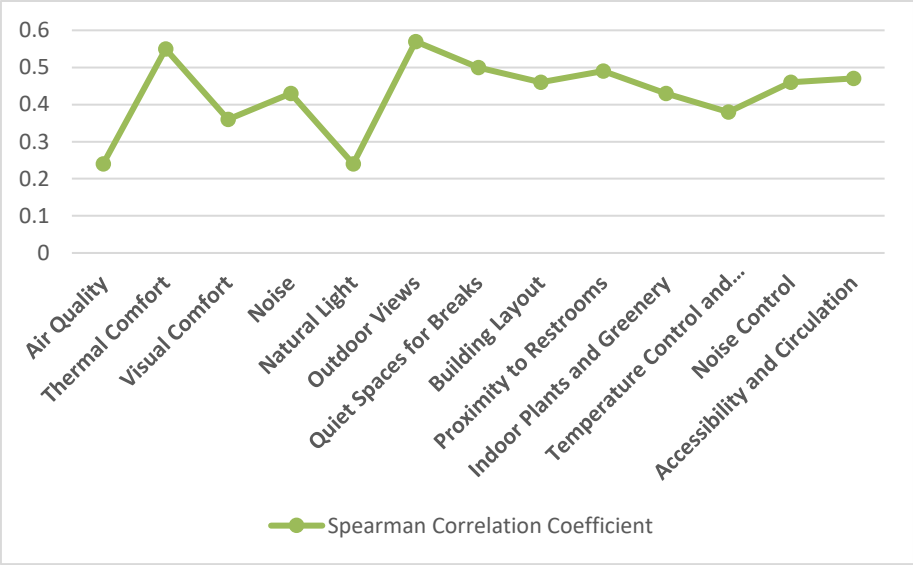

Figure 6. The results of the Spearman Correlation Coefficients for the different variables.

4.2 Observations

Observations were conducted by the design team, using Ackley et al.'s checklist as a guide and benchmark, as outlined in Table 7. The quality of the thermal comfort scored very well, as the temperature within different spaces of the hospital was measured using a digital thermometer, and it was consistently within the preferred range of 21-24 °C. Additionally, the building's entrance is located on the East with consideration of the orientation, and the building is constructed with concrete which provides thermal mass and insulative properties to mitigate temperature variation. To observe measures related to the air quality, the research team searched for openable windows and adequate mixed ventilation techniques, however there were not present inside the hospital. The CO2 levels were not measured due to the lack of access to the appropriate measurement equipment.

Table 7. Checklist based on design recommendations to improve indoor environmental quality in healthcare buildings.

IEQ Parameter	Indicator	Presence
Thermal Comfort	Temperature between 21-24 °C	✓
	Good building orientation/shading for solar control	✓
	Appropriate materials to mitigate temperature variation	✓
	Good wall, floor, roof insulation	✓
	Openable windows	✗
	Adequate mixed ventilation techniques	✗
Acoustics	Noise level < 45 dB(A)	✓
	Flexibility to open and close doors and windows	✗
	Absorbent materials	✗
	Signages and instructions to reduce noise	✗
Visual Comfort	Maximized window size	✗
	Good building orientation	✓
	Flexible shading to prevent glare	✗
	Material colour and reflectance	✗

As for the acoustics, the noise levels were measured in different zones and they were always below 45 decibels, in line with Ackley's work. Absorbent materials such as curtains and rugs were not found within the hospital, except for some of the patient rooms. There were also no signs of any educational instructions to reduce noise within the hospital. Having an appropriate orientation was the only architectural factor that was found to improve the visual comfort within the hospital. The windows in the building were small and located only in the outer patient rooms. The corridors and circulation areas had no windows or natural light, as depicted in Figure 7. Additionally, there was a lack of flexible shading, colour, and reflective materials.

Figure 7. Lack of windows and natural daylight in circulation areas within the selected hospital.

5. Discussion

5.1 Assessing the Impact of the Indoor Environmental Quality on Well-Being

To address the main research question which addresses the impact of the IEQ on the well-being of occupants within the selected hospital in Bahrain, the results of the questionnaire and observations were triangulated. The findings of the study highlight that the majority of hospital occupants selected 'comfortable' when asked to rate their overall physical comfort and well-being at the hospital. Most of them also claimed that they 'sometimes' experience physical symptoms that could be related to the indoor environment. These findings are consistent with common experiences in HVAC-controlled environments where overcooling can possibly lead to physical symptoms as individuals experience discomfort due to cooler temperatures (Liu et al., 2024a). Table 8 presents the key findings from the questionnaire and the observations to triangulate and interpret the results.

The results support the hypothesis that IEQ significantly impacts occupants' well-being in Bahraini hospitals. Regarding the IEQ variables, the questionnaire and observations indicate that visual comfort scored the lowest possibly due to the lack of daylighting in the building. The air quality scored the highest due to the adequate ventilation and absence of unpleasant smells in the hospital. Additionally, the thermal comfort is adequate due to the temperature being within an acceptable range, however, the acoustics can be improved. The findings also suggest that the lack of outdoor views confirms why occupants believe that their presence could enhance their well-being. The literature on air quality in Bahrain indicates the levels of ambient air pollution are very high, which could impact indoor environments, however the findings from the study show that the scores for the indoor air quality of the hospital are high, representative of occupant satisfaction (Amoatey et al., 2018). The scores of the air quality show that occupant don't have any worries about the quality of the air, which is why they perceive it as having little to no impact on their well-being. Furthermore, in a previous study on the IEQ within governmental buildings in Bahrain, the building layout and the ventilation system had the highest impacts on the indoor environmental quality and the well-being of occupants, however, in this study, although they still scored relatively high, outdoor views and thermal comfort scored slightly higher, possibly due to the limited windows within the building (Albuainain et al., 2021).

Table 8. Triangulation of the questionnaire and observations findings.

Variables Assessed	Questionnaire Findings	Observations Findings	Interpretation of Findings
Indoor Environmental Quality Variables	● 'Good' rating for all four variables ● Air Quality has highest mean ● Thermal comfort has second highest mean ● Noise second to lowest mean ● Visual Comfort has lowest mean	● No sufficient daylighting ● No openable windows ● Temperature within acceptable range ● No absorbent materials or signages	● Visual comfort low due to lack of daylighting ● Air quality good due to absence of unpleasant smells ● Thermal comfort good because temperature within acceptable range ● Acoustics can be improved
Architectural Factors Impacting Well-being	● Outdoor views and thermal comfort impact well-being the most ● Natural light and air quality impact well-being the least	● No outdoor views ● No daylight ● Adequate air quality and temperature	● Lack of outdoor views confirms why occupants believe it could enhance their well-being ● Good air quality causes occupants not to worry about it, impacting their well-being the least

The results suggest that although hospital occupants are satisfied with the indoor environment, their perceptions of IE variables and architectural factors impacting their well-being vary. The observations demonstrated that the hospital environment did not include many elements to support Ulrich's Theory of Supportive Design such as adjustable settings for a sense of control, or positive distractions such as green elements and views. However, social spaces were present for feelings of social support. Visual comfort including outdoor views has the most impact on occupants' well-being. Based on the interpretations of the results, the authors propose design recommendations (see Figure 8) to enhance the IEQ to support the well-being of occupants. Regarding the thermal comfort, a comfortable temperature should be maintained at all times, openable windows should be adopted, and the building layout should be adequate for heat distribution and ventilation. Mixed ventilation techniques should be used especially in the winter months to enhance the air quality and flow. Indoor plants, an advanced HVAC system, and regular monitoring of the air quality should be conducted. To improve the acoustics, absorbent materials should be integrated in the furniture such as seating, carpets, and curtains, and instructions should be visually present to advise occupants to reduce noise. More windows need to be integrated in the building to allow for natural light and views to the outside. The use of flexible shading, reflective materials, and colour can also help to mitigate glare, and enhance the visual comfort of occupants. It is essential for stakeholders to review and prioririze the proposed recommendations based on the hospital's financial capabilities and availability of resources. The proposed recommendations aim to enhance the IEQ of the hospital environment, aligned with principles of healing architecture designed for enhancing the healing process of occupants within healthcare settings (Jablonska & Furmanczyk, 2024). Architects and designers have the opportunity to contribute to the well-being of building users through careful design of the physical environment.

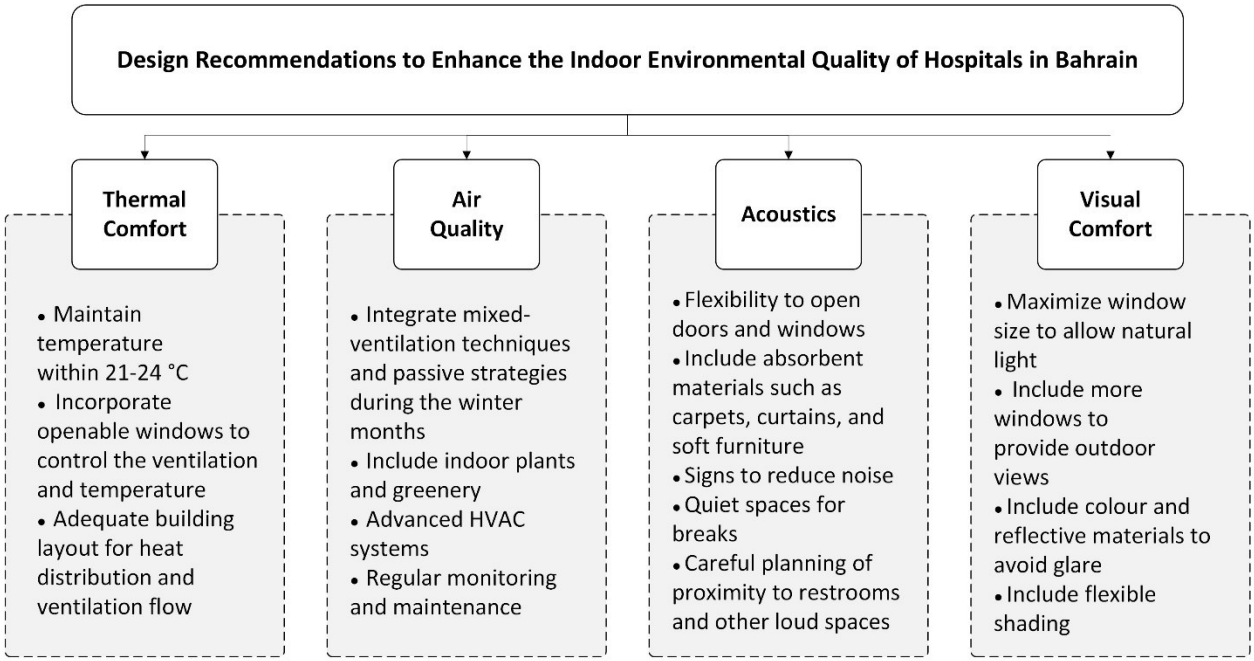

Figure 8. Proposed design recommendations to enhance the quality of the indoor environment to support the well-being of occupants.

6. Conclusion

Summary of Key Findings

This study investigated occupant perceptions of well-being and the IEQ at one of the leading private hospitals in Bahrain. The current state of the hospital was examined, and the triangulated results were used to assess the impact of the IEQ on well-being. The results highlight the impact of various variables on the well-being of hospital occupants. The occupants of the hospital were mostly satisfied with the indoor environment, and particularly with regards to the air quality inside the hospital. Although most of the occupants expressed positive perspectives regarding the acoustics, thermal comfort, and visual comfort, the visual comfort category had the lowest scores, possibly due to the limited windows, daylighting, and outdoor views within the hospital. Outdoor views and thermal comfort are the factors that impact occupant well-being the most in the hospital, in line with Kaplan's Attention Restorative Theory and Ulrich's Theory of Supportive Design, whilst natural light and air quality impact well-being the least. These findings could be due to the lack of daylighting and the non existence of an air quality issue. Based on the findings, the authors proposed design recommendations to enhance the IEQ to support the well-being of occupants at the hospital.

Limitations and Recommendations for Future Research

The authors acknowledge a few limitations in the study. The first is related to the nature of the self-administered questionnaire, as further empirical research is required such as physical measurements and monitoring of the indoor environment to assess occupant well-being. Additionally, future research could integrate other sampling techniques to investigate the perceptions of patients and visitors after visiting the hospital for some time, as the results might be affected by the condition of the participants at a particular time. Factors such as staff shift patterns can be included for more nuanced findings. Empirical data such as CO2 levels and light readings can also be included in future research. Moreover, studies on additional private and public hospitals in the country can enrich the results allow for more generalized perceptions. Future studies involving multiple hospitals and combining subjective and objective environmental measures would improve the external validity of the findings.

The study aims to fill a research gap in literature regarding the limited studies on indoor environmental quality and its affect on well-being in healthcare buildings in Bahrain. Visual comfort impacts hospital occupants' well-being the most in the selected Bahraini hospital. The proposed recommendations serve as a guide for designers and stakeholders to enhance the quality of life in hospitals in Bahrain and in the GCC region. The findings help stakeholders understand the implications of the indoor environment

as well as the impact of architectural factors on the well-being of hospital occupants, for more user-centered design approaches and in increasing the quality of life.

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