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Analyzing the Perception of Indoor Air Quality (IAQ) from a Survey of New Townhouse Residents in Dubai

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Abstract: According to UAE Health Ministry and Dubai Healthcare City reports, 15% of Dubai residents have a chronic respiratory disease such as asthma. Moreover, 90% of the 150,000 patients at Al Ain Hospital suffered from upper respiratory tract respiratory diseases, bronchitis, or asthma. Sick Building Syndrome (SBS) has emerged as a social problem in the United Arab Emirates (UAE). The Dubai Municipality regulates Indoor Air Quality (IAQ) with strict stipulations before moving in, but they are relatively passive about regulations related to healthy living. This paper aims to explore the actual state of perception of the IAQ from townhouse residents in Dubai, UAE. The characteristics of the resident's perceptions of the IAQ are identified, and the influential factors affecting residents' perceptions of IAQ are extracted. As a methodology, the survey was conducted on four townhouse projects in Dubai from December 2021 to January 2022. A total of 114 copies were distributed, and 98 documents were used. Analysis of the survey data was processed using IBM SPSS Statistics 26.0. The results showed a statistically significant correlation between the cognitive and anxiety levels of SBS with the presence or absence of experience. It was statistically confirmed that the most influential factors were the age of the children and the occupancy time of housewives and children. This is because of the perception that wives who spend a relatively long time in the house and their young children are exposed to indoor air pollution for a long period of time and are easily affected by this influence on the concerns about young children about SBS. Ninety-five percent of the respondents answered that they knew more than average about SBS, indicating a very high level of awareness. As for the degree of anxiety, 87.0% of the respondents felt higher levels of anxiety than usual. However, most of them did not know or were indifferent to the understanding of the air quality improvement methods. The awareness of actual contents was lower than that of residents who assessed that they knew about SBS.

Keywords: IAQ (Indoor Air Quality); SBS (Sick Building Syndrome); SBS symptom perception; influential factors; United Arab Emirates

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1. Introduction

According to UAE Health Ministry and Dubai Healthcare City reports, 15% of Dubai residents have a chronic respiratory disease such as asthma [1]. Moreover, 90% of the 150,000 patients at Al Ain Hospital suffered from upper respiratory tract respiratory diseases, bronchitis, or asthma [2]. Sick Building Syndrome (SBS), known to cause stinging eyes, sore throat and nose, headache, vomiting, and skin diseases, has emerged as a social problem in the United Arab Emirates (UAE) [3,4]. Due to unprecedented urbanization, UAE has built many new residential projects with poor choices of material and ventilation. This social phenomenon leads UAE to SBS faster than any other country [5].

To raise awareness of SBS, the Dubai Municipality regulates the Indoor Air Quality (IAQ) with the stipulation of less than 0.08 ppm (parts per million) of formaldehyde, less than 300 micrograms/m^3 of TVOC (Total Volatile Organic Compound), and less than

150 micrograms/m^3 of suspended particulates (less than 10 microns) in 8 h of continuous monitoring before occupancy [6,7].

Knowledge of government policies and self-investigation have increased regarding Indoor Air Quality (IAQ) before people move into homes [8]. However, they are relatively passive about guidance and systems related to healthy living after moving in [9,10]. A series of procedures and policies associated with IAQ ultimately aim to ensure residents' health and safety [11].

IAQ, after moving in, requires continuous IAQ management because there are multiple sources of pollutants, such as daily living and newly purchased electronic products, furniture, and bedding [12,13]. Nevertheless, it still needs to be active to identify and manage the status of actual residents after moving in [14].

Currently, most of the developers in Dubai are designing, constructing, and maintaining the new apartment buildings with eco-friendly materials, ventilation paths, ventilation facilities, and bake-outs before residents move in to comply with the recommended standards for indoor air quality [15,16]. Although this differs among construction companies, using eco-friendly materials and installing ventilation facilities are essential due to the institutionalization of mandatory ventilation facilities and the implementation of the housing performance rating system [17,18].

In this regard, after moving in, residents need to make efforts to improve the indoor air environment by actively using ventilation facilities and limiting the use of household items that can generate pollutants to lower the concentration of pollutants indoors [19]. Efforts to maintain or improve the indoor air environment created by the construction company and the contractor are required [20,21].

This paper aims to investigate the actual state of perception of the IAQ from townhouse residents in Dubai, UAE. Based on this, it seeks to extract important variables for indoor air environment perception, provides information to constructors, designers, and residents, and uses it as primary data for follow-up studies to improve IAQ. The specific objectives of the paper are as follows. First, the characteristics of townhouse residents' perceptions of the IAQ are identified. Second, the main factors affecting residents' perception of indoor air quality are extracted.

2. Materials and Methods

2.1. Literature Review

The research on IAQ in residential buildings conducted on a global scale since 2010 includes a survey on the actual conditions via measurements, a survey on residents' consciousness, and a study on indoor air pollutants control measures [22,23]. Among them, surveys on the exact condition through measurement and research on indoor air quality control methods are being actively conducted [24,25]. Regarding the correlation between IAQ and thermal comfort, Shan et al. (2016) [26] found that mixing ventilation (MV) could lead to significantly larger overall draft sensation than passive displacement ventilation (PDV) due to high air velocity from overhead diffusers. PDV, on the other hand, led to significantly higher drafts and colder sensations in the lower body level, while draft distribution was perceived relatively homogenously in the vertical direction in the MV room. Seating arrangements could lead to inhomogeneous sensations in the horizontal direction in both the MV and PDV rooms.

A higher CO_2 concentration was the main factor causing SBS related to the head, while both a higher CO_2 concentration and lower relative humidity (RH) contributed to SBS related to the eyes. Zuo et al. found that increasing the relative humidity from 50% to 70% at 26 and 30 °C had no significant effects on the subjects' physiological responses, thermal comfort, perceived air quality, or SBS symptoms. However, when the temperature was elevated to 37 °C, the heart rate, respiration rate, respiratory ventilation rate, mean skin temperature, and eardrum temperature increased significantly as a result of the increase in the relative humidity from 50% to 70%. The subjects felt hotter and more uncomfortable, and they found the indoor air quality to be less acceptable [26–28].

In the survey of residents' awareness, the degree of their awareness of SBS was investigated as 95.1% in the Wang et al. (2022) study and reported a high cognitive level [29]. In addition, Kim et al. (2019) said that the group with SBS had more knowledge about SBS than the group with no experience [30]. If they became nauseated for no reason after moving, they suspected SBS and reported more anxiety as if they had SBS [31,32].

Suzuki et al. (2021) reported that SBS symptoms were higher in wives and children who spent a relatively longer time in the house than their husbands [33]. It was concluded that it is related to the occupancy time in the home rather than gender differences. Wang et al. (2022) classified reactions such as dizziness, skin irritation, respiratory disease, insomnia, low motivation, and vomiting/nausea as 'strong symptoms' among the symptoms of SBS. In addition, reactions such as chemical odor, eye disease, and coughing/sneezing were classified as 'mild symptoms' [29], and Jung et al. (2022) mentioned that the respondents tended to complain more about mild symptoms [34]. Sarkhosh et al. (2021) said that the symptoms of SBS were frequently experienced in the following order: nasal disease, eye disease, and migraines [35].

Regarding the number of occurrences of SBS, Mentese et al. (2020) used the interview to find that most cases included one SBS symptom experienced by the residents, and cases where the residents experienced two to three symptoms were evaluated as normal [36]. In the case of men, it was reported that eye, nose, and skin diseases appeared more frequently in women in the following order: eye disease, skin disease, and fatigue [37].

Meanwhile, previous studies reported the results of residents' perceptions regarding their satisfaction with indoor air quality, indoor air pollution sources, measures to improve indoor air quality, and the application of eco-friendly building technology [38].

Yang et al. (2020) reported that satisfaction with IAQ was lower than that of the house's surrounding environment and interior space in an urban apartment with green certification in the western part of Switzerland, and there was no difference in satisfaction according to floor height [39]. However, the Sun et al. (2019) study reports that high-rise residents tend to have high dissatisfaction levels, but this does not suggest a possible cause [40].

In addition, several studies showed that housing materials, finishing materials, and enclosed indoor spaces were prioritized as the sources of indoor air pollution perceived by residents [41]. It was reported that other sources of pollution were purchased furniture, electronic products, and combustion facilities such as gas stoves [42,43].

Most of the IAQ improvement rooms carried out by residents were ventilation using windows, plant cultivation for air purification, and the use of charcoal [44]. In other words, it can be analyzed that measures to improve indoor air quality after moving in by residents tend to prefer low-cost and simple coping methods rather than methods that require specialized skills or cost a lot of money [45].

It was also reported that although there was a difference in the rankings for the prevention of SBS, the ratio of choosing eco-friendly building materials, indoor gardens (purifying plants), and increasing the number of ventilation (mechanical ventilation, natural ventilation) was high [46,47].

When selecting a method for improving indoor air quality, the most significant criterion is 'high effect,' and the rate of SBS experience and preference for high effect tend to be proportional. However, it was found that most residents were unwilling to pay or pay a small number of costs incurred by the application [48,49]. Tran et al. (2020) reported that 71.8% of residents did not intend to pay or said they would pay USD 50 or less in a survey of residents of new housing in the metropolitan area [13].

In other words, although residents positively perceive the use of eco-friendly building technology, it can be interpreted that they are not willing to pay the actual cost, which is judged to show regional differences [50,51]. In the prior studies described above, the term SBS is the most essential and representative concept related to indoor air quality. As factors with a relationship with SBS perception, it is used to analyze the factors associated with SBS awareness, experience, and relationship to anxiety, and real-time, in-house perception of pollution sources, pollution causes, and payment costs [52]. However, since these reports only note the results of general trends with a focus on the fact-finding of variables affecting the resident's consciousness, there are limitations to the structural interpretation and application of the resident's consciousness related to IAQ.

2.2. Survey Content and Method

The survey was conducted on four townhouse projects in Dubai: Dubai Hills, Arabian Ranches II, Damac Hills, and Nshama Townsquare (Figure 1) [53–56]. Among the four townhouse projects, three were constructed 24 to 30 months ago, and one was 42 months ago, showing a difference in the number of years since construction (Table 1).

Figure 1. Target Townhouse Projects ((**Upper Left**): Dubai Hills, (**Upper Right**): Arabian Ranches II, (**Bottom Left**): Damac Hills, (**Bottom Right**): Nshama Town Square).

Table 1. Target townhouse project overview.

Area	Project Name	Units	Completion	Elapsed Period after Construction
Mohammed Bin Rashid City	Dubai Hills	4600	July 2019	30 months
Dubai Lifestyle City	Arabian Ranches II	4000	July 2019	30 months
Dubai Land	Damac Hills	3008	July 2018	42 months
Dubai Land	Nshama Town Square	3500	January 2020	24 months

From December 2021 to January 2022, 114 copies of the questionnaire were distributed during the investigation, and 98 were completed (85.96% effective). The survey data were analyzed using IBM SPSS Statistics 26.0.

The questionnaire was divided into the general matters of residents, including interior finishing materials and renovation status, awareness and experience of SBS, recognition of indoor air pollutants and polluted spaces, and perceptions of indoor air quality improvement plans concerning previous research [57].

The residents' general information consisted of the residents' gender, age, average monthly income, home ownership type, residence period, number of families, and family composition. Regarding interior finishing materials and remodeling, the types of finishing materials for each space, the quality of remodeling (multiple responses), and newly purchased items were investigated [58]. As for the questions, the perception and experience of SBS, the perception and anxiety level of SBS, whether or not there was an experience, the status of experiences by family, and types of symptoms were identified [59].

To recognize indoor air pollution sources and polluted spaces, indoor air pollution sources were selected up to the third priority [44]. A survey was conducted on an area perceived as a polluted space that required comfort.

Lastly, the survey on the perception of indoor air quality improvement measures consisted of questions about each effect and cost of applying eco-friendly building technology, the intention to pay the price per square meter, and the technology to be used [60].

3. Results

3.1. Residents' General Information

Tables 2–5 provide general information about the surveyed residents. The distribution of family composition and the number of residents is 32.65% in the case of a couple and three children (family of 5), 28.57% in the case of a couple and two children (family of 4), and a couple and one child (family of 3) was 18.36%. It was found that ex-pats with a large family with three or more people reflect the regional characteristics of Dubai citizens who prefer to live in townhouses (Table 2) [61].

Table 2. Resident Family Composition.

Classification		Number (%)
Household Type (Number of Family Members)	Single Household (1 People)	1 (1.02)
	Couple Household (2 People)	8 (8.16)
	Mother & 1 Child (2 People)	2 (2.04)
	Couple & 1 Child (3 People)	18 (18.36)
	Couple & 2 Children (4 People)	28 (28.57)
	Couple & 3 Children (5 People)	32 (32.65)
	Couple & 3+ Children (5+ People)	9 (9.18)
	Total	98 (100.0)

Table 3. Age Group and Occupational Distribution.

Classification		Couple Household (Number (%))	
		Husband	Wife
Age Group	The 20s	4 (4.2%)	10 (10.5%)
	The 30s	24 (25.3%)	22 (23.2%)
	The 40s	35 (36.8%)	38 (40.0%)
	The 50s	32 (33.7%)	25 (26.3%)
	Total	95 (100.0%)	95 (100.0%)
Occupation	Stay-at-home wife/husband	0 (0.0%)	38 (41.1%)
	Service	7 (7.4%)	12 (12.6%)
	Government	5 (5.3%)	8 (8.4%)
	Office	24 (25.3%)	14 (14.7%)
	Professional	21 (22.1%)	7 (7.4%)
	Managerial	26 (27.4%)	10 (10.5%)
	Self-Employed	12 (12.5%)	5 (5.3%)
		95 (100.0%)	95 (100.0%)

Table 4. Children's Age Group Distribution.

Classification	Number (%)			
	First Child	Second Child	Third Child	Fourth Child
Infancy (0–1 years)	8 (7.5%)	-	-	-
Early childhood (2–6 years old)	16 (15.2%)	12 (16.7%)	-	-
Childhood (7–12 years old)	24 (22.6%)	20 (27.7%)	5 (62.5%)	-
Adolescence (13–18 years old)	32 (30.2%)	18 (25.0%)	2 (25.0%)	1 (50.0%)
Early adulthood (19–30 years old)	26 (24.5%)	22 (30.6%)	1 (12.5%)	1 (50.0%)
Total	106 (100.0%)	72 (100.0%)	8 (100.0%)	2 (100.0%)

Table 5. Resident's Average Monthly Income, Ownership, and Period of Residence.

Classification		Number (%)
Average Monthly Income	Below AED 10,000	1 (1.0%)
	AED 10,000–20,000	5 (5.1%)
	AED 20,000–30,000	13 (13.3%)
	AED 30,000–40,000	31 (31.6%)
	Above AED 40,000	48 (49.0%)
	Total	98 (100.0%)
Home Ownership	Own	72 (73.5%)
	Rent	26 (26.5%)
	Total	98 (100.0%)
Period of Residence	Less than 6 months	9 (9.2%)
	7–12 months	13 (13.3%)
	13–18 months	40 (40.8%)
	19–24 months	19 (19.4%)
	More than 25 months	17 (17.3%)
	Total	98 (100.0%)

As for the husband's age, those in their 40s (36.8%) and 50s (33.7%) showed the highest ratio, and the highest percentages of wives were in their 40s (40.0%). As for husbands' occupations, 27.4% worked as a manager, 25.3% were office workers, and 41.1% did not work outside the home. This suggests that the wife will spend significant time within her home (Table 3).

In addition, the age distribution for children is shown in Table 4, and 48 (45.3%) of the firstborn children were in their infancy and childhood, and 32 (44.4%) of the second-born children.

As for the average monthly income of the surveyed residents, 49.0% answered AED 40,000 or more, and 31.6% answered AED 30,000–40,000 [62]. Those with AED 30,000 or more accounted for 80.6% of the total, which was found to be in the top 25% income bracket in Dubai [63]. A total of 73.5% of the respondents owned their homes, and the period of residence between 13 and 18 months was 40.8% (Table 5).

3.2. Interior Finishing Materials and Renovation Status

Tables 6 and 7 show the status of interior finishing materials and renovation of the houses under investigation. Among the survey spaces, the master bedroom, children's room, living room, and kitchen were classified as the main spaces. The balcony, utility room, toilet, and entrance were divided into auxiliary areas [44].

Table 6. Main Space Finishing Materials.

		Number (%)			
		Master Bedroom	**Children's Room**	**Living Room**	**Kitchen**
Wall	Paper-based Wallpaper	-	-	2 (2.1%)	1 (1.0%)
	PVC Wallpaper	36 (36.7%)	31 (31.6%)	38 (38.7%)	18 (18.4%)
	Water-based Paint	58 (59.2%)	64 (65.3%)	52 (53.0%)	44 (44.9%)
	Tile	-	-	4 (4.1%)	32 (32.7%)
	Miscellaneous	4 (4.1%)	3 (3.1%)	2 (2.1%)	3 (3.0%)
	Total	98 (100.0%)	98 (100.0%)	98 (100.0%)	98 (100.0%)
Floor	PVC Flooring	9 (9.1%)	4 (4.1%)	-	12 (12.2%)
	Marble	15 (15.3%)	10 (10.2%)	49 (50.0%)	3 (3.1%)
	Plywood Flooring	28 (28.6%)	33 (33.7%)	13 (13.3%)	23 (23.5%)
	Tile	44 (44.9%)	48 (48.9%)	34 (34.6%)	57 (58.1%)
	Miscellaneous	2 (2.1%)	3 (3.1%)	2 (2.1%)	3 (3.1%)
	Total	98 (100.0%)	98 (100.0%)	98 (100.0%)	98 (100.0%)

Table 7. Auxiliary Space Finishing Materials.

		Number (%)			
		Balcony	**Multi-Purpose Room**	**Bathroom**	**Entrance Hall**
Wall	Paper-based Wallpaper	-	-	-	-
	PVC Wallpaper	-	7 (7.1%)	6 (6.1%)	54 (55.1%)
	Water-based Paint	76 (77.6%)	74 (75.5%)	2 (2.1%)	26 (26.5%)
	Tile	18 (18.4%)	15 (15.3%)	86 (87.8%)	15 (15.3%)
	Miscellaneous	4 (4.0%)	2 (2.1%)	4 (4.0%)	3 (3.1%)
	Total	98 (100.0%)	98 (100.0%)	98 (100.0%)	98 (100.0%)
Floor	PVC Flooring	2 (2.1%)	4 (4.0%)	3 (3.1%)	4 (4.0%)
	Marble	-	-	-	64 (65.3%)
	Plywood Flooring	-	18 (18.4%)	-	2 (2.1%)
	Tile	94 (95.8%)	72 (73.6%)	93 (94.8%)	26 (26.5%)
	Miscellaneous	2 (2.1%)	4 (4.0%)	2 (2.1%)	2 (2.1%)
	Total	98 (100.0%)	98 (100.0%)	98 (100.0%)	98 (100.0%)

Table 6 shows that water-based paint showed the highest percentage of wall finishing materials in the main space. The floor finishing materials were installed in the order of tile, plywood flooring, and marble. The use of marble flooring was highest at 50.0% in the living room.

In the case of auxiliary space, water-based paint was the highest for wall finishing materials for the balcony and multi-purpose room, and various materials were used for the entrance hall. In terms of floor finishing, it was found that more than 80% of the spaces were tiled except the entrance hall (Table 7).

The items purchased after moving in were classified into electronic products, furniture, and bedding. The number of electronic products purchased after moving in was higher than that of furniture. Items that showed the highest number of purchases included furniture, desks/chairs and bookshelves/display cabinets made of wood, which are predicted to be the primary pollutants of indoor air, (Table 8).

Table 8. Purchased Items After Moving In (Multiple Responses).

Electronic Products	Number	Furniture	Number	Bedding	Number
TV	78	Bookshelf/Display Cabinet	66	Pillow	56
Washing Machine	48	Desk/Chair	62	Blanket	52
Microwave	42	Sofa	52	Curtain	44
Refrigerator	40	Dining Table	48	Cushion	30
Computer	37	Wardrobe	34	Electric Blanket	29
Air Conditioner	38	Dressing Table	25	Carpet	20
DVD/Audio Equipment	33	Shoe Closet	12	Miscellaneous	3
Total	316	Total	299	Total	234

3.3. The Awareness and Experience of SBS

As shown in Table 9, the level of awareness of SBS was 10.0% 'I know it very well, 46.0% 'I know it, and 38.0% 'Average Knowledge,' indicating that 95.0% of the total were aware of SBS. In addition, anxiety about SBS was above average in 87.0%, excluding 1.0% of 'not anxious at all' and 12.0% of 'not anxious.'

Table 9. Awareness Level of SBS.

Recognition Level	Number (%)	Anxiety Level	Number (%)
I don't know at all	2 (2.0%)	Not anxious at all	1 (1.0%)
I do not know	3 (3.0%)	Not anxious	12 (12.0%)
Average Knowledge	38 (38.0%)	Average anxiety	52 (52.0%)
I know	46 (46.0%)	Anxious	29 (29.0%)
I know it very well	11 (11.0%)	Very anxious	6 (6.0%)
Total	100 (100.0%)	Total	100 (100.0%)

The survey results by dividing the occupancy time in a house into less than 8 h, more than 8 h, less than 12 h, and more than 12 h are as follows: husbands showed the highest ratio between 8 h and less than 12 h. Wives and children showed the highest percentage of occupancy time of more than 12 h, indicating that wives and children spend more time at home.

SBS consists of mucous membrane irritation of the eyes, nose, and throat, headache and migraine, nausea, respiratory diseases; and, less frequently, dry or itchy skin. As for the number of cases of SBS experienced by each family member, as shown in Table 10, the symptoms that showed a high distribution among husbands, wives, and children were eye diseases, headaches, and skin diseases. In the case of husbands, other symptoms, such as fatigue and decreased reproductive function, were reported [64].

Table 10. Number of SBS Symptoms by Family Member (Multiple Responses).

SBS Symptoms	Husband	Wife	Child 1	Child 2	Child 3	Total
Eye disease	3	15	5	2	1	26
Migraine headache	5	11	4	2	0	22
Nausea	0	1	0	0	0	1
Respiratory diseases	1	2	1	0	1	5
Skin disease	2	6	4	2	2	16
Decreased reproductive function	5	0	0	0	0	5
Fatigue	4	2	0	0	0	6
Dyspnea (Short Breath)	1	1	0	0	0	2
Nasal disease	0	7	3	1	1	12
Dizziness	0	2	0	0	0	2
Tension	0	1	0	0	0	1
Loss of concentration	0	1	0	0	0	1
Total	21	48	17	7	5	98

3.4. Recognition of Indoor Air Pollutants and Polluted Spaces

Table 11 shows the results of repeated responses to the third priority for indoor air pollution causes. As a result of the first-priority responses, it was found that housing materials and finishing materials, enclosed indoor spaces, and inflow of air pollutants from the outside of the house were recognized as essential factors. In the second-priority responses, the influx of air pollutants were at a high rate, including housing materials and finishing materials in enclosed indoor spaces and the outside of the house. In response to the third-priority responses, it was recognized that the inflow of air pollutants from outside the home and newly purchased furniture were also factors [65].

Table 11. Awareness of Indoor Air Pollution Causes.

Pollution Cause	1st Priority	2nd Priority	3rd Priority
	Number (%)	Number (%)	Number (%)
Finishing materials	34 (35.4)	22 (24.2)	11 (13.1)
Enclosed indoor space	32 (33.3)	22 (24.2)	8 (9.5)
The inflow of air pollutants from outside the house	15 (15.6)	17 (18.7)	21 (25.0)
New furniture	9 (9.4)	12 (13.2)	16 (19.0)
New electronics	4 (4.2)	8 (8.8)	12 (14.3)
Cookware	2 (2.1)	5 (5.5)	12 (14.3)
New curtains	2 (2.1)	4 (4.4)	1 (1.2)
Miscellaneous	0 (0.0)	1 (1.1)	3 (3.6)
Toral	98 (100.0)	91 (100.0)	84 (100.0)

This study found that housing and finishing materials, enclosed indoor spaces, air pollutants inflow outside the house and newly purchased furniture were noted as areas of concern. These results are different from that of previous studies. In the study of D'alessandro et al. (2020), it was reported that the responses to materials and finishing materials, enclosed indoor spaces, and newly purchased electronic products were high, and responses involving the exterior of the house and newly purchased furniture were reported to be very low [66]. In the study of Amoatey et al. (2018), materials and combustion facilities were recognized as the primary internal factors of indoor air [67]. Canha et al.'s (2017) study reported that the primary indoor pollutants were identified in the order of housing materials, enclosed indoor spaces, electronic products, and cooking utensils [68].

Therefore, the recognition of the inflow from outside the house, which is characteristic of this study, is judged to be the result of representing the fine dust from the desert climate, which is a regional characteristic [69].

On the other hand, the survey results on spaces perceived as highly likely to be polluted and spaces that require comfort are shown in Figure 2. In that order, the areas perceived as having a high possibility of contamination were the kitchen and bathroom. Spaces requiring relative comfort were found in the order of living room, kitchen, and bathroom.

This indicates that a high level of comfort is required for the kitchen and bathroom, which require exceptional cleanliness. It is recognized that there is a high possibility of contamination or a space where family members spend a long time together. The master bedroom, children's room, and living room are recognized as spaces that require comfort and have a low degree of possibility of contamination, so they are judged as stable spaces for generating pollutants.

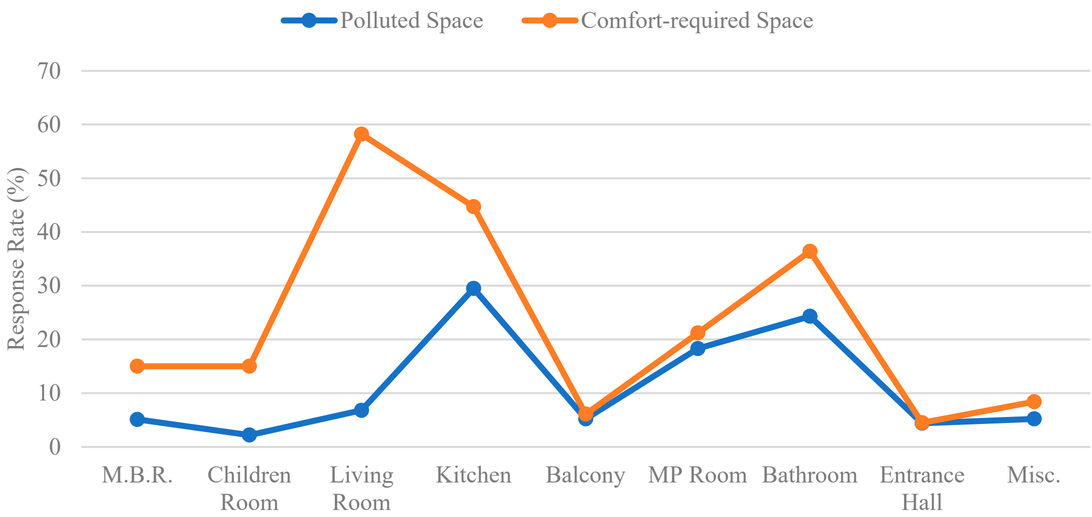

Figure 2. The Relationship between the Perception of Polluted Space and the Comfort-required Space.

However, spaces such as kitchens, balconies, multi-purpose rooms, bathrooms, and entrance halls do not show a clear difference in the demand for comfortable space and recognition as a space with the possibility of contamination.

3.5. Awareness of Measures to Improve Indoor Air Quality

The survey on the perception of indoor air quality improvement measures evaluated by residents is primarily based on the developer's perception of improvement, the perception of the effect and cost of the progress, the intention to apply the improvement plan, and the intention to pay the price per sqm.

3.5.1. Awareness of the Improvement from the Developer

Before residents moved in, the perception of the developers on the improvement measures for indoor air quality was investigated. This is a survey on whether or not residents are aware of the developer's implementation by dividing it into eco-friendly building material construction, catalyst construction, air purifiers, mechanical ventilation systems, flat plan considering natural wind, and bake-out.

In previous studies, it has been reported that almost no guidance or explanation from the construction company is received on SBS prevention [70]. This survey also found that the contractor was unaware of the improvement plan or the degree of effectiveness (Table 12). This is thought to be due to the lack of interest from residents, the lack of active improvement plans, and no guidance from the developers. Therefore, the vigorous exercise of residents' right to know and interest is required (Table 13).

Table 12. Developer's Awareness of the IAQ Improvement Plan.

Awareness	Eco-Friendly Material (%)	Catalysts (%)	Air Purifier (%)	Mechanical Ventilation (%)	Natural Ventilation (%)	Bake-Out (%)
Yes	7	4	11	12	7	4
No	93	96	89	88	93	96
Total	100	100	100	100	100	100

Table 13. Degree of IAQ Improvement.

Residents Evaluation	Eco-Friendly Material (%)	Catalysts (%)	Air Purifier (%)	Mechanical Ventilation (%)	Natural Ventilation (%)	Bake-Out (%)
Very Improved	1	0	0	0	0	0
Improved	3	1	4	1	4	4
Average	3	3	4	5	1	2
Not Improved	3	2	1	1	2	0
Indifference	90	94	91	93	93	94
Total	100	100	100	100	100	100

3.5.2. Awareness of the Effectiveness and Cost

The perception of effectiveness and cost for five items of eco-friendly building materials, air purifier, mechanical ventilation system, natural ventilation system, and bake-out was investigated using the seven-step Likert scale. A score of 1 was given for a shallow effect, a score of 2 for a low effect, a score of 3 for a slightly soft effect, a score of 4 for a moderate effect, a score of 5 for a somewhat high effect, a score of 6 to a high effect, and a score of 7 to a very high effect.

As for the effect of each indoor air quality improvement method, Figure 3 evaluated it as having more than 'average' in all five items. It was found that natural ventilation (5.12 points) was perceived as having a 'slightly high effect.' Regarding the remaining items, bake-out (4.91 points), eco-friendly building materials (4.75 points), mechanical ventilation (4.74 points), and air purifier (4.66 points).

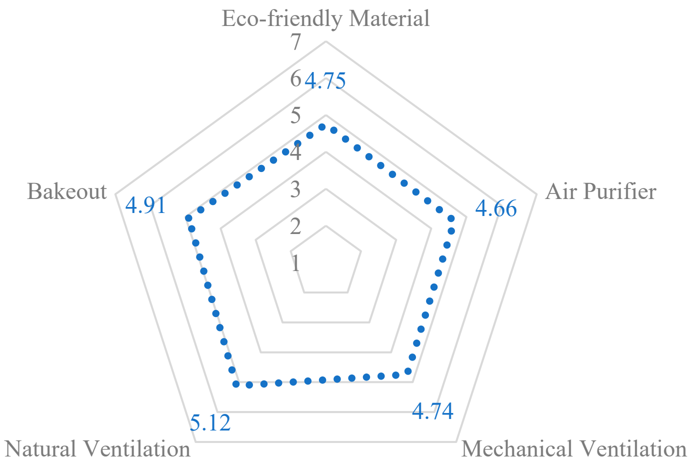

Figure 3. The Level of Recognition for Different IAQ Improvement Methods.

Regarding the cost of the indoor air quality improvement methods, 1 is very low cost, 2 is low cost, 3 is slightly low cost, 4 is average, 5 is somewhat high cost, 6 is high cost, and 7 is very high cost. As shown in Figure 4, most of the perceptions of 'normal' appeared in all five items, and among them, 'Mechanical Ventilation' (4.76 points) was recognized as the most expensive technique. In the remaining items, 'Bakeout' (4.71 points), 'Eco-friendly Materials' (4.62 points), 'Air Purifiers' (4.44 points), and 'Natural Ventilation' (4.35 points) were considered to require low cost in that order.

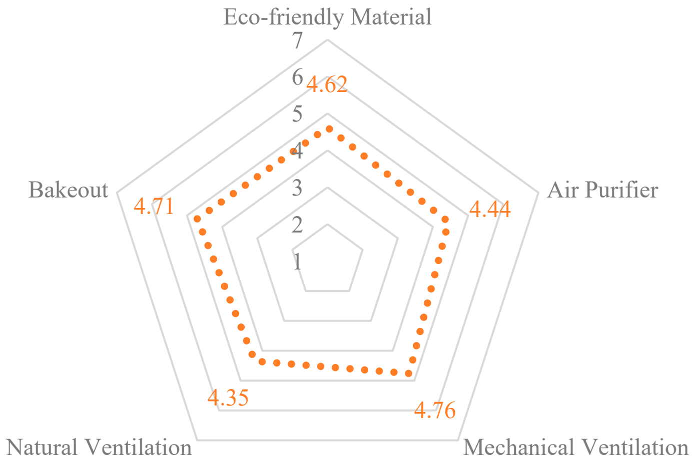

Figure 4. Awareness of the Effects and Cost of Each Method of Improving IAQ.

In other words, residents are highly aware of the direct effects of the improvement methods that residents can access. In terms of cost, it is recognized that the lowest price is required, so it is judged that preference for it is high.

3.5.3. Residents' Intent on Application Options

As shown in Table 14, the residents' intention to apply the indoor air quality improvement method showed that the Eco-friendly Materials, Air Purifiers, and Natural Ventilation had a relatively higher choice to use than the Bake-out and Mechanical Ventilation systems. This is believed to be related to the perception of their prices. It is judged that they showed a low preference for mechanical ventilation systems and bake-out, which were recognized as requiring relatively high prices.

Table 14. Residents' Intent on Application Options.

Intention	Eco-Friendly Material (Number (%))	Air Purifier (Number (%))	Mechanical Ventilation (Number (%))	Natural Ventilation (Number (%))	Bake-Out (Number (%))
Yes	86 (87.8)	79 (86.8)	59 (67.0)	82 (86.3)	71 (75.5)
No	12 (12.2)	12 (13.2)	29 (33.0)	13 (13.7)	23 (24.5)
Total	98 (100.0)	91 (100.0)	88 (100.0)	95 (100.0)	94 (100.0)

3.5.4. Residents' Intent to Pay per Square Meter

Table 15 shows the willingness to pay per sqm when applying a new method to reduce indoor air pollution. From 'AED 200 or less' to 'AED 600 or more', about 85.72% were willing to pay, and 14.28% were unwilling to pay. In the previous study, Fu et al. (2019) reported that 37.2% of the respondents did not want to pay the cost [71]. However, in this study, it was found that about 85% of the residents were willing to pay—70.41% were willing to pay less than AED 400. This result shows an active intention to pay for indoor air quality improvement. Whether this change in perception is a national or a climate difference needs to be confirmed in future studies.

3.6. Awareness of Measures to Improve Indoor Air Quality

In this study, SBS recognition and anxiety levels were divided into subjective cognitive scales and analyzed to understand the scientific structure of variables related to residents' perception of indoor air quality.

Table 15. Residents' Intent to Pay per Square Meter.

Cost	Willingness to Pay	
	Number	Percent
Lower than AED 200	41	41.83
AED 200–400	28	28.58
AED 400–600	9	9.18
Higher than AED 600	6	6.13
No willingness to pay	14	14.28
Total	98	100.00

3.6.1. Analysis of the Relationship between Subjective Cognitive Variables and Other Variables

Table 16 shows the results of analyzing the correlation between subjective perception variables of cognition and anxiety about SBS. There was a significant correlation between the two variables, and the deeper the cognition, the more severe the anxiety.

Table 16. Relationships among Variables related to SBS Perception.

Classification	Level of Recognition	Level of Anxiety	Experienced or Not
	Person Correlation Coefficient (Two-Sided Significance Level)		Chi-Square (Two-Sided Significance Level)
Level of Recognition	1 (0.000)	-	**10.358 (0.034)**
Level of Anxiety	**0.421 ** (0.000)**	1 (0.000)	**35.94 (0.000)**

** Correlation coefficient is significant at the 0.01 level (both sides).

In addition, the presence or absence of the experience of SBS was found to have a significant correlation with the degree of cognition and anxiety. It is analyzed that the degree of recognition is more profound, and the degree of anxiety is higher than the case without experience. It is consistent with the report by Nakayama et al. (2019) that the experienced group of SBS had more knowledge about SBS and had more anxiety than the inexperienced group [72].

In particular, the degree of awareness of SBS showed a significant correlation with children's real-time time. The understanding of SBS increased when the first and second children had an extended stay. In addition, it was found that the wife's real-time hours, children's age, and monthly average income were significant in terms of anxiety about SBS. The longer the wife's occupancy time, the younger the children's age, and the higher the average monthly income, the more severe the instability. It was found that given a significant amount of time spent in the house will result in significant exposure to indoor air pollution. Therefore the probability of the occurrence of SBS is relatively high (Table 17).

3.6.2. Extraction of Major Influential Variables for Each Subjective Cognitive Variable

The explanatory power of each variable was inferred by performing regression analysis on the variables that can be assumed to be correlated with the subjective cognitive variables. It was found that the most explanatory power for the recognition level of SBS was the anxiety level and the child's lifetime, and the explanatory power of this relational expression was 47.2% (Table 18).

Table 17. The Correlation between Subjective Cognitive Variables of SBS and Other Variables.

Classification	Level of Recognition	Level of Anxiety
	Person Correlation Coefficient (Two-Sided Significance Level)	
Husband Age	−0.027 (0.833)	−0.063 (0.612)
Wife Age	0.018 (0.890)	−0.047 (0.702)
1st Child Age	0.043 (0.743)	−0.103 (0.433)
2nd Child Age	0.158 (0.369)	**−0.401 * (0.019)**
Duration of Residence	−0.035 (0.732)	0.045 (0.659)
Average Monthly Income	0.092 (0.367)	**0.212 * (0.038)**
Husband Occupancy Time	0.036 (0.827)	0.298 (0.065)
Wife Occupancy Time	0.066 (0.673)	**0.402 ** (0.009)**
1st Child Occupancy Time	**0.418 * (0.017)**	0.332 (0.062)
2nd Child Occupancy Time	**0.572 ** (0.009)**	0.412 (0.072)
Willingness to Pay	0.009 (0.930)	−0.152 (0.140)

** Correlation coefficient is significant at the 0.01 level (both sides). * Correlation coefficient is significant at the 0.05 level (both sides).

Table 18. Results of Regression Analysis on the Level of Recognition for SBS.

Classification	Level of Recognition				
	Standardized Beta Coefficient	Partial Correlation Coefficient	F Value	Significance Level	R Square
1st Child Occupancy Time	−0.482	−0.258	3.367	0.036	0.472
2nd Child Occupancy Time	0.088	0.046			
Experienced or Not	−0.265	−0.251			
Level of Anxiety	−0.524	−0.426			

In addition, among the variables related to the degree of anxiety about SBS, it was found that the child's age had the most significant explanatory power, and the explanatory power of this model was 76.6% (Table 19).

Table 19. Results of Regression Analysis on the Level of Anxiety in SBS.

Classification	Level of Anxiety				
	Standardized Beta Coefficient	Partial Correlation Coefficient	F-Value	Significance Level	R Square
1st Child Age	2.258	0.496	7.664	0.001	0.766
2nd Child Age	−2.365	−0.515			
Wife Occupancy Time	0.263	0.395			
Experienced or Not	−0.745	−0.814			
Level of Recognition	−0.274	−0.428			

4. Discussion

Recently, many people have complained of various symptoms such as itchiness, dizziness, headache, and skin problems after moving into a new townhouse. This symptom varies from person to person and is known to be due to Sick Building Syndrome (SBS), which is caused by many toxic substances in the indoor air of new buildings. However, due to IAQ laws and broadcasting in UAE, concerns about SBS have become a significant topic of interest, and interest in health is increasing. However, there are few studies on stimulatory symptoms in relation to SBS, indicating that the academic community has yet to address this phenomenon.

In the case of the research in the medical field, most of the content is related to the actual condition of chemical factors, such as the assessment of health risk factors caused by indoor air pollution and the symptoms and reactions that residents experience that are not addressed in this study. In this context, this study investigated residents' health awareness symptoms and responses toward SBS, which will continue to be discussed as an essential issue in Dubai's rapidly spreading townhouse development.

While previous research focused on studying hazardous chemicals in new apartments, this study provides data on the subjective effects of SBS's multifaceted specific data by focusing on the symptoms or reactions that residents consciously experience. It is expected that the social impact in terms of improving the quality of life of the new townhouse residents will be significant.

5. Conclusions

The characteristics in the overall perception of IAQ were identified for townhouse residents, and the main factors affecting the perception of IAQ were extracted. The key points of discussion and conclusions of this study are detailed below.

(1) There is a statistically significant correlation between the cognitive level and anxiety level of SBS with the presence or absence of experience. It was statistically confirmed that the most influential factors were the age of the children and the occupancy time of housewives and children. Based on these results, the main factors influencing the cognition and anxiety level of SBS were extracted as the real-time in-house residence and the age of the children.

This is because of the perception that wives who spend a relatively long time in the house and their young children are exposed to indoor air pollution for a long time and are easily affected by the concerns for the health of their young children and SBS.

(2) Regarding SBS, 95.0% of the respondents answered that they knew more than average about SBS, indicating a very high level of awareness. As for the degree of anxiety, 87.0% of the respondents felt higher anxiety levels than usual. However, in reality, it was found that most of the residents did not know or were indifferent to the understanding of the air quality improvement methods or the improvements made by the contractor. It was found that the awareness of the actual contents was lower than that of residents who assessed that they knew about SBS.

In other words, although they are aware of the SBS, the lack of awareness and indifference to the details and whether or not air quality improvements were implemented is considered to have acted as factors in increasing anxiety. Therefore, we found that residents need to show interest and effort to acquire information voluntarily, and construction companies should be required to actively provide and share information through various methods.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: New data were created or analyzed in this study. Data will be shared upon request and consideration of the authors.

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