Orkomi *Archives of Public Health* (2024) 82:247
https://doi.org/10.1186/s13690-024-01486-z

Archives of Public Health

RESEARCH

Open Access

Impacts of environmental parameters on sick building syndrome prevalence among residents: a walk-through survey in Rasht, Iran

Ali Ahmadi Orkomi[1*]

Abstract

Background This study evaluated the prevalence of sick building syndrome (SBS) in Rasht, Iran, a subtropical climate with wetter cold season city, during the autumn and winter months of 2020, focusing on the effects of noise and ventilation.

Methods A total of 420 residents completed the indoor air climate questionnaire (MM040EA), and a walk-through survey of 45 randomly selected residential units assessed environmental noise, ventilation rate, and luminous conditions.

Results Approximately 38.2% reported SBS symptoms in the past three months. Significant associations were found between SBS and dim light (P-value = 0.012, OR = 2.1, CI = 1.09-4), noise (P-value = 0.031, OR = 1.75, CI = 1.1–2.9), passive smoking (P-value < 0.01, OR = 2.6, CI = 1.22–5.4), static electricity (P-value < 0.01, OR = 3.8, CI = 1.15–12.6), bad air (P-value < 0.01, OR = 4.6, CI = 1.6–13), and high room temperature (P-value = 0.039, OR = 2.6, CI = 1.13–5.95) at $\alpha = 0.05$. The field survey revealed that 75.5% of units exceeded the national noise threshold of 55 dBA. The average ventilation rate was 20 lit/(p.sec), while 32% of the units reported low or moderate lighting during daytime hours. No significant association was found between the type of interior wall finishing or heating systems and SBS. Stronger correlation was observed between noise and SBS in districts with higher traffic-induced noise.

Conclusion Considering high noise levels in residential areas, local authorities must prioritize noise insulation policies in building design and construction.

Keywords Noise, Questionnaire, Residential, SBS, Ventilation rate

*Correspondence:
Ali Ahmadi Orkomi
Orkomi@guilan.ac.ir
[1] Department of Environmental Sciences, Faculty of Natural Resources, University of Guilan, Someh Sara, Guilan, Iran

Text box 1. Contributions to the literature

- We analyzed the impact of environmental noise on SBS in residential units, addressing a key research gap.
- Direct measurement of ventilation rates and noise levels has been conducted across a diverse array of 45 dwelling units.
- The prevalence of Sick Building Syndrome (SBS) in residential settings and its links to local climate and cultural factors had not been thoroughly studied in Iran before this.

Background

Sick building syndrome is a widely recognized phenomenon characterized by a range of symptoms, which are often linked to the quality of the indoor environment. SBS, as opposed to BRI, typically manifests as symptoms that diminish upon leaving the affected environment [30]. In modern society, individuals are increasingly spending more time indoors [24, 36]. This trend, along with energy-saving strategies that limit ventilation rates in enclosed areas, as well as increasing traffic-related air and noise pollution in residential and commercial buildings, has raised concerns about the potential impact of poor indoor air quality and other environmental factors on human health. The causes of SBS are multifaceted and complex including improper air quality [46], noise [5, 19], illumination [21] and thermal discomfort [17]. Poor indoor air quality, a widely acknowledged major contributor [16, 43, 46], is often a result of factors such as inadequate ventilation rates and the presence of chemical, biological, and airborne contaminants [40, 50]. Additionally, psychological factors may also play a role in the development of SBS symptoms [12, 29].

In today's modern society, the growing psychological and emotional burden of urban living has decreased individuals' tolerance to environmental stressors, leading to an increase in SBS symptoms in residential settings [12, 26]. Common symptoms of SBS reported in the literature include irritation of the upper respiratory system and eyes, general or neurotoxic effects, dermal symptoms, and complaints of odor and taste [24].

SBS was first identified in the late 1800s, leading to various studies on its causes, effects, and mitigation strategies in residential [44], official [12], and healthcare [2] settings. A cross-sectional study in Japan with 4996 participants found a 26.9% prevalence of SBS, with younger individuals and women more likely to report symptoms [44].

Takigawa et al. [45] studied the effects of VOCs on SBS symptoms in 260 small Japanese residences, using the MM040EA questionnaire during 2004 and 2005. The findings indicated a prevalence of SBS symptoms at approximately 13.5% in 2004 and 11.5% in 2005. Furthermore, an association between hydrocarbon concentrations and the risk of SBS symptoms was obtained in bedrooms. Shao et al. [39] studied SBS in 1281 Nanjing residents, finding a prevalence under 15%. They linked skin-related symptoms to the building's age and floor area, while factors such as painted walls, $PM_{2.5}$ levels, and smoking were significantly associated with general symptoms.

Sun et al. [42] reported a significant association between ventilation rates, ozone, and ultrafine particles and mucosal symptoms in 32 dwelling units in China, while formaldehyde and VOC concentrations did not exhibit a significant correlation with SBS. Lu et al. [23] showed a significant positive correlation between outdoor SO_2 concentration and nose symptoms, as well as outdoor temperature and fatigue and eye symptoms, among 3,485 parents in China. Assessing elderlies' exposure to PM_{10}, $PM_{2.5}$, CO and CO_2 concentration has been studied by Abdel-Salam [1] in 28 residences of Alexandria city, Egypt. Although the elderlies spent 63% and 33% of their time in bedrooms and living rooms, their exposure to air pollutants was higher in the living rooms.

Sarkhosh et al. [38] found a 70.1% prevalence of SBS symptoms among 154 municipality office workers in Mashhad, Iran, using a decision tree approach. Additionally, job satisfaction and VOC concentrations were identified as the most significant parameters. Miao and Ding [25] reported that 63% of Chinese public buildings had poor thermal conditions and 33% of respondents preferred lower air conditioning airflow. Additionally, 83% reported environmental noise, primarily from traffic and social activities. Niven et al. [27] revealed that forced air conditioned office buildings outperformed naturally ventilated buildings in terms of lower SBS symptoms and more desired ventilation rate and noise level. Also, they reported positive correlation between low frequency ventilation noise and SBS symptoms. The same results have been reported by Burt [6]. Guan et al. [15] investigated the combined effects of noise and temperature on comfort perception among 18 young office participants and revealed that increased noise levels corresponded with greater discomfort.

The impacts of noise, ventilation and lighting on the prevalence of SBS have been substantially investigated in healthcare units (Rashid and Zimring [33]; USA; Keyvani et al. [22], Iran; Arikan et al. [5], Turkey; Kalender Smajlović et al. [21], Slovenia) and office settings (Jafari et al. [19]; Iran; Niven et al. [27], UK; Witterseh et al. [47]; Denmark). Notably, the existing scientific literature lacks reports on environmental SPL monitoring at dwelling units and its impact on SBS symptom perception. In the study conducted by Orkomi and Bora [28], traffic-induced noise mapping in Rasht city revealed that the daytime, nighttime, and daily SPL in residential areas exceeded standard limits.

To address these gaps, the present survey assesses the influence of environmental noise in the living rooms of residents. Additionally, the ventilation/infiltration rate is obtained through inert CO_2 gas concentration monitoring in dwelling units. The main questions addressed in the article include the amount of SBS prevalence in dwelling units of Rasht city, the association between SBS and environmental noise in different urban districts of Rasht, and the impact of ventilation/infiltration rates on SBS in Rasht.

Materials and methods

Study area

Rasht, the capital city of Guilan Province, is the most populous city in north-central Iran (Fig. 1). Nestled at 37°16’50"N and 49°34’59"E, Rasht experiences a humid subtropical climate. As of the latest census in 2016, Rasht is home to around 680,000 inhabitants [14]. The city is divided into five municipality districts (Fig. 1), each with nearly an equal distribution of the population, approximately 20% per district. The population density in districts one through five is recorded at 78, 209, 84, 61, and 34 individuals per hectare, respectively. Rasht City annually receives an average rainfall of approximately 1357 mm [13]. Long-term meteorological data (2007–2021) analysis in Climate Consultant V.6 software indicates that July (26 °C) and February (8 °C) are the hottest and coldest months on average in Rasht, respectively. Other monthly climate parameters (illumination, cloud cover and daily pattern of monthly averaged temperature/RH are reported as complementary files (ESM_1, ESM_2 and ESM_3).

Questionnaire and the criteria

The standard indoor air quality MM040EA questionnaire [4] was translated into Farsi and made available to participants both in face-to-face and online formats. Throughout

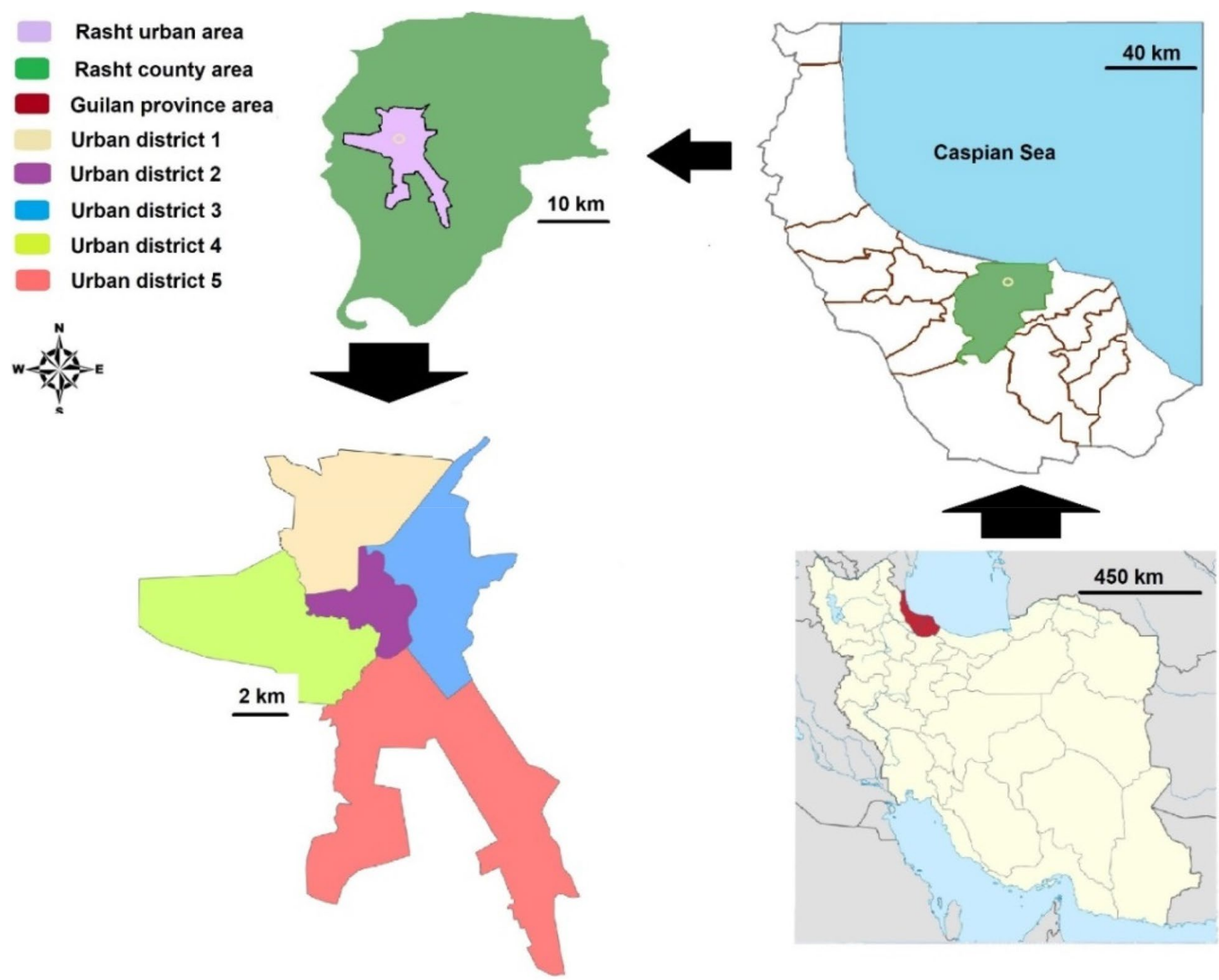

Fig. 1 The situation of Rasht city and its five districts in Guilan Province, Iran

the questionnaire completion process (October 2020 to January 2021), an expert was present alongside the participant, either physically or virtually, to address any potential ambiguities. The survey comprised 33 questions: 5 on personal information and residence, 4 on medical history and smoking, 12 on SBS symptoms, and 12 on irritating physical factors. The questions related to SBS symptoms and irritating factors were designed as three-options (never, sometimes, often) scale.

Taking into account a 95% confidence interval, a desired precision of 5%, and the assumption that 50% of the population exhibits SBS symptoms, the required sample size for a large population is determined to be 384 [7]. Assuming 10% illegibility, we opted for a 10% oversampling. As this study was conducted in residential environments, where SBS factors are typically less severe than in hospitals [21], the documentation of even a single SBS-related symptom is significant. Consequently, individuals who reported at least one general, mucosal, or dermal symptom on a weekly basis, considered as positive cases of SBS [18, 37]. It should be mentioned that the questionnaire also asked the respondents "If they presumed the positive symptoms are related to their indoor area?". As the respondents had difficulties to answer this question, their respond had not been considered in the analysis. The Pearson's Chi-squared test [31] and Fisher's exact test [10] were executed using MS Excel 2016, while logistic regression analysis was carried out in MEDCalc software version 32.0.2, with a significance threshold established at 5%.

Monitoring SBS related parameters

A walk-through survey was conducted to monitor environmental and building-related factors reported by questionnaire participants. 45 dwelling units from the five districts of Rasht city have been selected randomly. After coordinating with the owners, two environmental experts (20 and 24 years old) visited the locations. A-weighted SPL were recorded with a TES 1358 A instrument, measuring noise from 30 to 130 dB with 1.5 dB precision. Measurements lasted 30 min in living rooms, with the sound level meter positioned at least one meter from walls and 1.6 m high. CO_2 concentration, temperature, and relative humidity were assessed using an AZ77535 device, accurate to 50 ppm for CO_2, 0.6 °C for temperature, and 3% for humidity, with time-weighted averages recorded indoors and outdoors over 20 min. Room dimensions were measured with a measuring tape, and data on wall finishes, heating systems, and building age were collected via a questionnaire. The relevant form and the filled questionnaire in the 45 residential units are provided in Online Resource 1 (ESM_4) and Online Resource 2 (ESM_5). Considering the impacts of heating system on indoor air pollution level and their usage during cold seasons, the impacts of heating system on the SBS symptoms have been assessed in this study. To assess the impacts of some observed risk factors of these 45 houses on SBS syndromes, the occupants filled out the same MM040EA questionnaire described in Sect. "Questionnaire and the criteria". The experiment campaign in a typical two-bedroom house is illustrated in Fig. 2.

The survey was conducted between November 2020 and February 2021, with all measurements performed during the period of 9:00–12:00 am to account for variations in traffic patterns and induced noise levels throughout the day. Most of the Residential units' owners agreed to visit in the mentioned time interval. Furthermore, prior to the experts' arrival, residents were asked to turn off heaters or any indoor combustion sources for at least one hour. The ventilation rate was determined using Eq. (1) considering the steady state CO_2 mass balance law inside the residential unit. As the carbon dioxide concentration is not uniform in indoor spaces, Eq. (1) may not be uniformly applicable to the entire area. Additionally, residents commonly spend time in the hall (living room), which is often separate from the bedrooms and kitchen in the interior plans of houses in Rasht city. Therefore, Eq. (1) is specifically applied in the hall and kitchen areas.

Ventilation rate

Considering a steady state mass balance with the source term for CO_2 in the interior space, the ventilation rate may be obtained using Eq. (1).

$$Q = \frac{10^6 \sum {}_1^n V_{CO_2,i}}{n \times \left(C_{CO_2}(in) - C_{CO2}(out)\right)} \tag{1}$$

in which Q, n, $V_{CO_2,i}$ and C_{CO_2} are the averaged ventilation rate per person (lit/(p.sec), number of occupants during the experiment, CO_2 generation rate (lit/sec) by person i and the measured CO_2 concentration (ppm). It has been assumed that the occupants are the only source of CO_2 indoor. Also, the CO_2 generation rate is calculated using Eq. (2) [32].

$$V_{CO_2} = 0.000179 \times BMR \times M \times (T/P) \tag{2}$$

Where BMR, M, T and P are the basal metabolic rate (MJ/day), the physical activity level (met), ambient temperature (K) and pressure (kPa), respectively. It should be noted that in derivation of Eq. (2), the ratio of CO_2 generation rate to oxygen consumption rate is assumed 0.85 [48]. The BMR parameter [20, 32] is a function of mean body mass, where the mean body mass is reported by EPA [9] and illustrated in Table 1. The physical activity level is different for various activities [3, 20]. In this study, the values for common activities at dwelling units are used (Table 1).

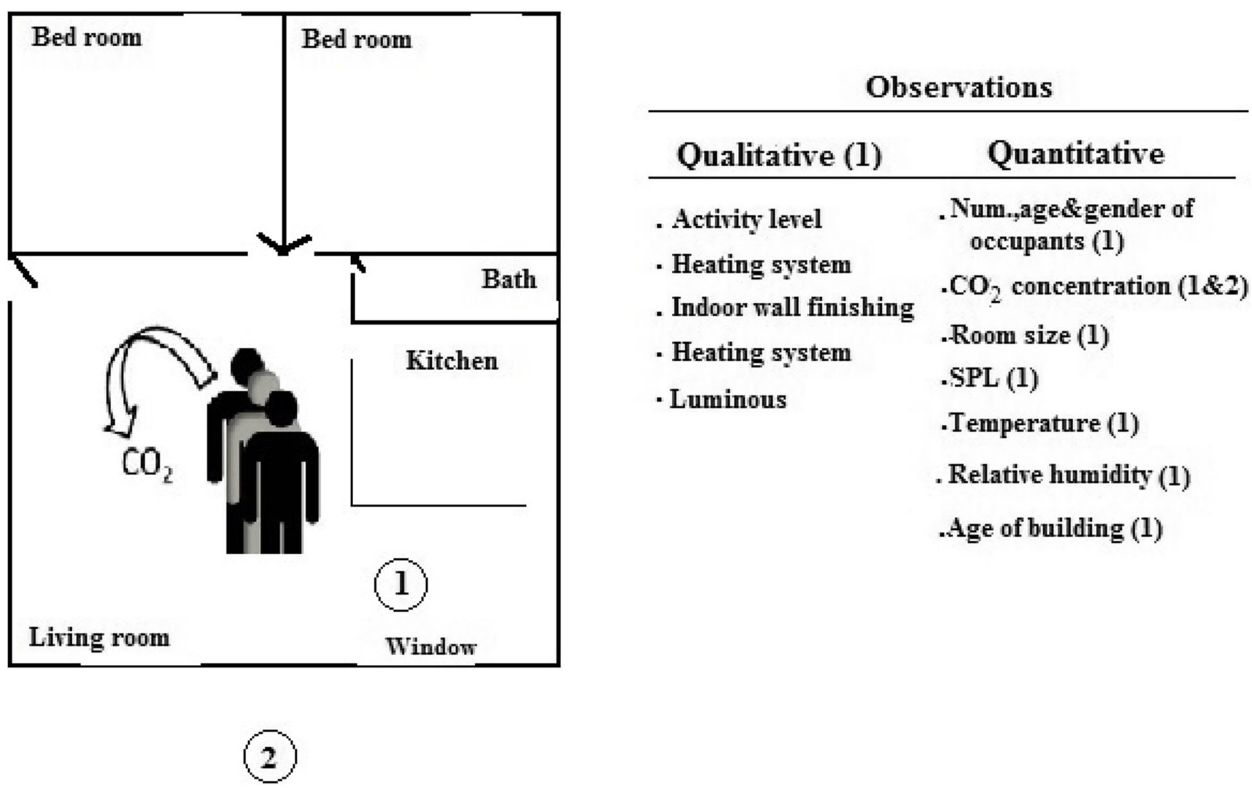

Fig. 2 Data gathering procedure in a typical dwelling unit

Limitations

The study was conducted amidst the COVID-19 pandemic, and it is worth considering the potential psychological effects resulting from the heightened awareness of disease spreading. This increased sensitivity may have led to a higher prevalence of SBS in residential units in Rasht. Furthermore, conducting noise assessments in various rooms throughout the day, as well as calculating individuals' daily exposure levels, could offer a more accurate assessment of the relationship between noise and SBS symptoms. Although, women spend more time in residential units than men do, the gender imbalance (75% women) of the present study may have an influence on the results. The selection of homogeneous samples in different urban districts can also enhance the validity of the results.

Results and discussion

Questionnaire results assessment

The statistical analysis revealed that out of the 420 individuals who participated from 407 dwelling units, 25% were male and 75% were female, with an average age of 33 years. 32 individuals were smokers (25 females and seven males), six individuals reported respiratory or dermal problems, and 39 individuals spent more than 10 h per day outdoor. Smokers, individuals with respiratory or dermal problems, and those who spent more than 10 h engaged in activities outdoors were considered as ineligible participants. Consequently, after filtering out the ineligible individuals, the questionnaires that were completed by 301 females and 57 males were considered eligible for further evaluation. The characteristics of the eligible participants are presented in Table 2. The youngest participant was a 16-year-old female, while the oldest was a 77-year-old man.

Out of 358 eligible individuals, approximately 38.2% of participants (comprising 117 females and 20 males) indicated that they had experienced at least one of the general, mucosal, or dermal symptoms weekly over the past three months, with no identifiable cause. The most frequently reported symptoms were general symptoms, noted by 28% of individuals. Dermal and mucosal symptoms followed as the second and third most common, reported by 15% and 10% of participants, respectively. The prominence of general symptoms aligns with findings from other studies conducted in residential environments [8, 42]. The prevalence of SBS symptoms was observed at 39% in females and 35% in males. Many studies reported higher prevalence of SBS in females than in males [12, 34], due to the difference in the perception,

Table 1 Body metabolism related parameters applied in Eq. (2)

Age (yr)	Sex	Mass (Kg)	BMR	Physical activity	Physical activity level M (met)
< 1	Male	8	1.86	Cleaning, sweeping	3.8
	Female	7.7	1.75		
1–3[a]	Male	12.8	3.05		
	Female	12.3	2.88		
3–6	Male	18.8	3.90	Kitchen activity	3.3
	Female	18.3	3.59		
6–11	Male	31.9	5.14		
	Female	31.7	4.73		
11–16	Male	57.6	7.02		
	Female	55.9	6.02	Sitting reading, writing, typing	1.3
16–21	Male	77.3	7.22		
	Female	65.9	6.12		
21–30	Male	84.9	8.24		
	Female	71.9	6.49	Sleeping	1.0
30–40	Male	87	7.83		
	Female	74.8	6.08		
40–50	Male	90.5	8.00		
	Female	77.1	6.16		
50–60	Male	89.5	7.95	Standing tasks, light effort	3.0
	Female	77.5	6.17		
60–70	Male	89.5	6.84		
	Female	76.8	5.67		
70–80	Male	83.9	6.57	Standing quietly	1.3
	Female	70.8	5.45		
≥ 80	Male	76.1	6.19		
	Female	64.1	5.19		

[a] Less than 3 years old

social roles, personality traits and physiological characteristics [5]. The share of females among the eligible participants is 82% and this imbalance may have an impact on the result. Nonetheless, the statistical analysis in this study revealed no significant association between gender and the prevalence of SBS symptoms (P-value = 0.59). The prevalence of each specific symptom related to sick building syndrome is detailed in Table 3.

Based on the data in Table 3, the most commonly reported symptom was fatigue, with a prevalence of 17.04%. Following that, concentration difficulty, headache, feeling of heaviness in the head, dry facial skin were the second to fifth most common symptoms, with prevalence rates of 12.01%, 11.45%, 10.06%, and 9.22%, respectively. The least reported symptom was nausea, with a prevalence of 1.12%.

According to the questionnaire results, noise was identified as the most significant irritating factor on a weekly basis by 22.91% of the study participants. Following this, the presence of dust and dirt and passive smoking were

Table 2 Demographic information of eligible participants

Parameter		*n*	%
Gender	Male	57	15.92
	Female	301	84.08
16 ≤ Age < 20	Male	10	2.79
	Female	24	6.70
20 ≤ Age < 30	Male	17	4.75
	Female	118	32.96
30 ≤ Age < 40	Male	8	2.23
	Female	54	15.08
40 ≤ Age < 50	Male	7	1.96
	Female	64	17.88
50 ≤ Age < 60	Male	10	2.79
	Female	32	8.94
Age ≥ 60	Male	5	1.40
	Female	9	2.51

Table 3 Sick building syndrome symptoms among participants in dwelling units

Prevalence		Yes (often)	Yes (sometimes)	No (never)
Symptoms		**n (%)**	**n (%)**	**n (%)**
General	Fatigue	61 (17.04)	190 (53.07)	107 (29.89)
	Heavy head	36 (10.06)	166 (46.37)	156 (43.58)
	Headache	41 (11.45)	153 (42.74)	164 (45.81)
	Nausea/Dizziness	4 (1.12)	74 (20.67)	280 (78.21)
	Concentration difficulty	43 (12.01)	162 (45.25)	153 (42.74)
Mucosal	Eye irritation	17 (4.75)	78 (21.79)	263 (73.46)
	Nose irritation	17 (4.75)	87 (24.30)	254 (70.95)
	Throat hoarse	10 (2.79)	122 (34.08)	226 (63.13)
	Cough	9 (2.51)	138 (38.55)	211 (58.94)
Dermal	Dry facial skin	33 (9.22)	99 (27.65)	226 (63.13)
	Itchy scalp/ears	21 (5.87)	118 (32.96)	219 (61.17)
	Dry hands	24 (6.70)	93 (25.98)	241 (67.32)

ranked as the second and third most significant factors, respectively, with a considerable margin between them and noise. These findings are presented in Table 4.

The statistical analysis assessing the impact of environmental factors on the prevalence of SBS symptoms identified significant associations between SBS prevalence and dim light (P-value = 0.012, OR = 2.1, CI = 1.09–4). Additionally, a notable correlation was found between SBS and noise pollution (P-value = 0.031, OR = 1.75, CI = 1.1–2.9), passive smoking (P-value < 0.01, OR = 2.6, CI = 1.22–5.4), static electricity (P-value < 0.01, OR = 3.8, CI = 1.15–12.6), bad air (P-value < 0.01, OR = 4.6, CI = 1.6–13), and too high room temperature (P-value = 0.039, OR = 2.6, CI = 1.13–5.95), with the significance level of $\alpha = 0.05$. However, as stated in Table 4, no significant associations were found between SBS and other independent parameters at a significance level of $\alpha = 0.05$. Besides, the association between four most prevalent symptoms and the affecting risk factors has been investigated via logistic regression in MedCalc statistical software. The association between fatigue, headache, heavy head and the concentration difficulty and 14 risk factors are expressed as Odds ratios in Fig. 3.

Figure 3 reveals that there is a positive association between static electricity and fatigue, where a negative association is observed between varying room temperature and fatigue. Heavy head was significantly associated with passive smoking (Fig. 3.b). In addition, passive smoking has a positive correlation with headache and concentration difficulties, where the association is more significant for headache (Fig. 3.c and d).

It was observed that all participants experiencing weekly static electricity were women (P-value = 0.002), likely due to indoor slippers that prevent static electricity dissipation. Moreover, when examining the sensation of high room temperature, a significant association was

Table 4 The prevalence of environmental factors among participants

Prevalence	Yes (often)	Yes (sometimes)	No (never)	*p*-value
Factor	***n* (%)**	***n* (%)**	***n* (%)**	**-**
Draught	27 (7.54)	161 (44.97)	170 (47.49)	0.160
Too high room temperature	25 (6.98)	181 (50.56)	152 (42.46)	0.039
Varying room temperature	31 (8.66)	179 (50.00)	148 (41.34)	0.330
Too low room temperature	26 (7.26)	166 (46.37)	166 (46.37)	0.680
Bad air	18 (5.03)	80 (22.35)	260 (72.63)	< 0.01
Dry air	6 (1.68)	91 (25.42)	261 (72.91)	0.150
Unpleasant odor	15 (4.19)	89 (24.86)	254 (70.95)	0.210
Static electricity	13 (3.63)	100 (27.93)	245 (68.44)	< 0.01
Passive smoking	32 (8.94)	97 (27.09)	229 (63.97)	< 0.01
Noise	82 (22.91)	181 (50.56)	95 (26.54)	0.031
Dim light	28 (7.82)	163 (45.53)	167 (46.65)	0.012
Dust and dirt	44 (12.29)	144 (40.22)	170 (47.49)	0.120

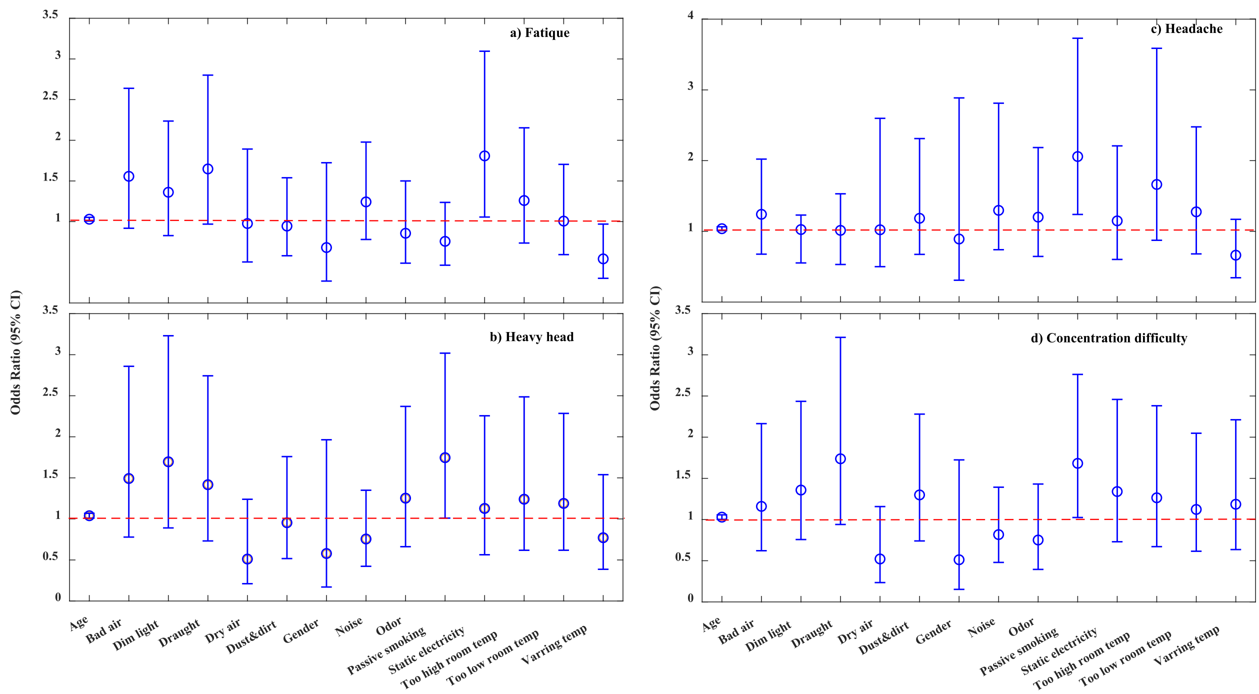

Fig. 3 Association between weekly prevalence of **a**) fatigue, **b** heavy head, **c** headache and **d**) concentration difficulty and 14 risk factors

noted between feeling high temperature and SBS symptoms in women (P-value = 0.025). However, no significant association was found among men (P-value = 0.555). One plausible explanation for this observation is the clothing style of women in Iran, which is influenced to some extent by Islamic culture. Older women, in particular, tend not to wear comfortable clothing indoors, leading to a perception of high temperatures among women. Segmenting females into three age groups (under 30, 30–40, and over 40 years) demonstrated a significant relationship between age and the perception of high indoor temperature (P-value = 0.016).

Given that traffic-induced noise pollution is a significant environmental concern in Rasht [28], the influence of noise as a factor affecting SBS is anticipated. Passive smoking and poor air quality (bad air) in residential units may also be attributed to inadequate ventilation. Moreover, the sensation of too high room temperature can be caused by a lack of proper ventilation in residential units or improper energy management in buildings.

Rasht is geographically divided into five urban districts (Fig. 1). Typically, residents in district one, located in the northern areas of the city, exhibit higher financial security compared to other districts, while residents in district five, located in the southern areas of the city, possess relatively lower financial security. Based on the questionnaire statistics, 27%, 20%, 12%, 31%, and 9% of the participants are residents of districts one to five, respectively. Upon analysis of the questionnaire results, it was found that 47% of the participants in district one reported experiencing at least one SBS symptom on a weekly basis. The corresponding percentages for districts two to five were identified as 42%, 26%, 32%, and 37% (Table 3). Among the environmental factors that significantly impacted SBS, only environmental noise exhibited variation across different urban districts, displaying a relatively distinct pattern. Consequently, the relationship between noise and SBS symptoms was separately examined in the five districts, with the results presented in Table 5.

The findings revealed the strongest association between SBS symptoms and noise in district four (OR = 4.13, CI = 1.7–10.2). Furthermore, district one (OR = 2.03) and five (OR = 1.5) exhibited significant associations. These outcomes are consistent with the fact that a major east-west transportation route of the province runs through district four. Additionally, district one experiences high traffic volumes due to the presence of numerous healthcare facilities, which subsequently leads to a significant impact of noise on the prevalence of SBS symptoms. Although the traffic noise is not an indoor factor, the improper acoustic design of buildings can enhance the noise impact indoors. Besides, the lack of considering noise map in residential land use planning as well as incompatibility of building acoustic with the background SPL increase the potential of SBS and BRI in Rasht city. Prolonged exposure to environmental noise

Table 5 Association between noise and SBS in five urban districts

District	Noise SBS	No	Yes (Weekly)	OR
1	No	44	7	2.03
	Yes(Weekly)	34	11	
2	No	30	11	0.68
	Yes(Weekly)	24	6	
3	No	26	5	0.52
	Yes(Weekly)	10	1	
4	No	62	12	4.13
	Yes(Weekly)	20	16	
5	No	15	5	1.50
	Yes(Weekly)	8	4	

can transform nonspecific symptoms into lasting physical, cardiovascular, and psychological BRIs [35].

In-situ measurement results of risk factors

To investigate the risk factors contributing to SBS in residential units in Rasht, a field study were conducted in 45 residential units, with results presented in ESM_5. The situation of six risk factors measured in the studied units are depicted in Fig. 4. The noise measurements in the living rooms of these units indicated that the average SPL over a 30-minute period ranged from 53 to 68 dBA. This exceeded the Iranian daytime standard limit of 55 dBA [28] in 75.5% of the examined residential units. It is signifying that the environmental noise level in residential units in Rasht is significantly high and is a major contributing factor to symptoms related to SBS, as also evident in the questionnaire results presented in the previous Sect. "Questionnaire results assessment".

As stated in Sect. "Questionnaire results assessment", inadequate ventilation is another major factor contributing to SBS in Rasht. The ventilation rate of the living rooms was measured using the direct measurement of CO_2 concentration and calculated using Eqs. (1) and (2). The calculation results showed that the average ventilation rate in the examined units was 20 L per

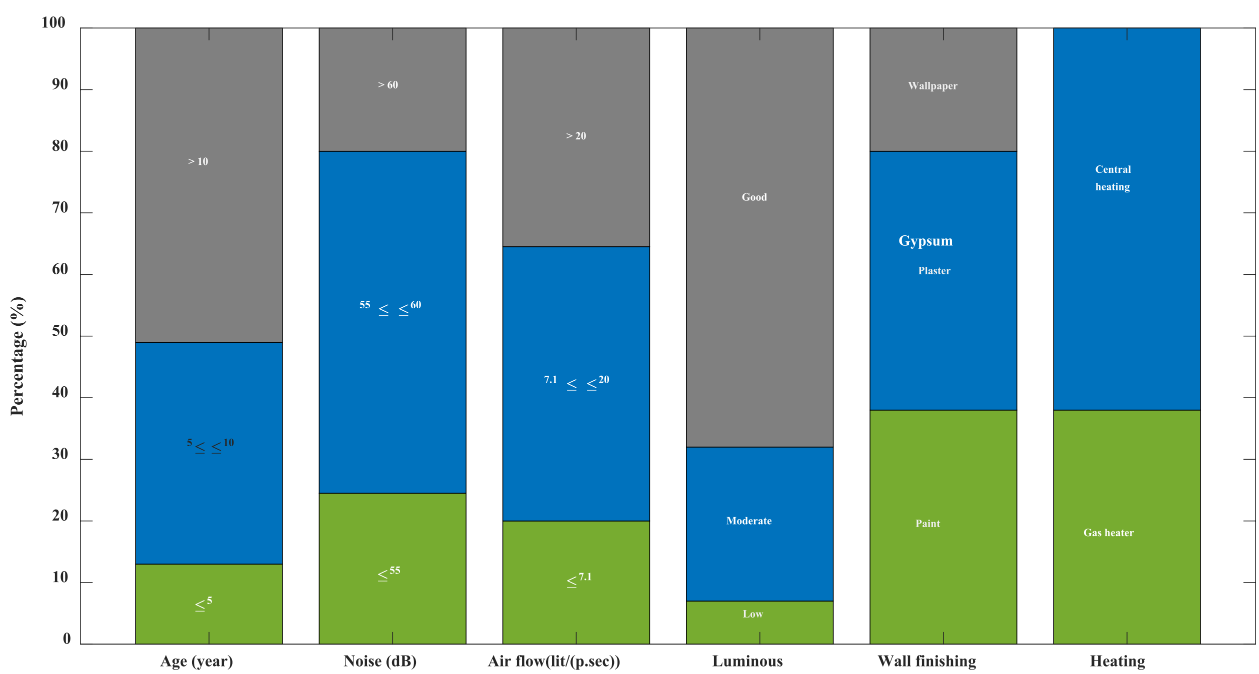

Fig. 4 The distribution of observed risk factors in 45 units

second per person, ranging from a minimum of 2.7 to a maximum of 63.5 lit/(p.sec). Nonetheless, 65% of the residential units had ventilation rates below 20 lit/(p.sec). According to Fig. 4, about 20% of the studied units had ventilation rates below the national code for the minimum amount of fresh air intake in residential units [11] (7.1 lit/(p.sec)), indicating inadequate ventilation directly affects various issues in residential units such as passive smoking, lack of access to fresh air, and increased room temperature.

Furthermore, dim light in residential units has been identified as a primary contributor to SBS according to the questionnaire survey results in Sect. "Questionnaire results assessment". It was observed that 32% of 45 units had either low or moderate lighting in the living rooms (Fig. 4), whereas the remaining residential units had adequate natural daylighting. In this regard, Siu-Yu Lau et al. [41] reported that 90% of respondents were satisfied with the luminous condition in living rooms of Hong Kong. Also, a research by Xue et al. [49] revealed that 54% of participants in Hong Kong reported luminous comfort in the living room, from which 60% satisfied with the daylight quality.

The residential units in Rasht and northern Iran are generally designed with larger windows in the living rooms than in the bedrooms, which leads to a reduced amount of natural light entering the bedrooms. The results revealed that satisfaction levels regarding natural light in residential units in Rasht were less than 70% (Fig. 4). However, natural light reception can also be influenced by factors such as weak sunlight during autumn and winter seasons, cloudy and rainy weather, solar altitude angle, building orientation, floor, and socio-cultural influences, which were not considered in this research and need further investigation.

The houses surveyed in this study had an average age of 14 years, ranging from 3 to 40 years. The statistical analysis revealed no significant relationship between the age of residential units and SBS symptoms at the alpha level of 0.05 (P-value = 0.66). The heating systems present in the units consisted of both central radiator heating and individual natural gas heaters, with 62% of the units employing central heating, while the remaining units utilized individual natural gas heaters (Fig. 4). There was no significant association observed between the type of heating system and SBS symptoms (P-value = 0.10).

Regarding interior walls, 38% of the units had painted interior walls, 42% were covered with gypsum plaster, and 20% utilized wallpaper (Fig. 4). The statistical results indicated no significant relationship between SBS symptoms and the use of paint for interior wall finishing, both overall and under different ventilation conditions, at the alpha level of 0.05 (P-value = 0.6).

Conclusion

The investigation aimed to assess the prevalence of SBS in residential units across all five urban districts of Rasht, the largest city in northern Iran, utilizing both a questionnaire and direct measurement of influential environmental parameters. A questionnaire was employed, and expert support was provided to individuals for its completion.

Analysis of the questionnaire results revealed that among 358 eligible individuals, around 38.2% of participants (117 females and 20 males) reported experiencing at least one of the general, mucosal, or dermatological symptoms on a weekly basis. While the prevalence of SBS symptoms was 39% in females and 35% in males, no significant association was found between gender and SBS prevalence.

The most prevalent SBS symptom was identified as fatigue, with a rate of 17.04%. Statistical analysis demonstrated significant associations at $\alpha = 0.05$ level between SBS symptoms and dim light (P-value = 0.012), noise pollution (P-value = 0.031), passive smoking (P-value < 0.01), static electricity (P-value < 0.01), bad air (P-value < 0.01), and too high room temperature (P-value = 0.039). The study also showed a stronger correlation between noise levels and SBS in areas with higher traffic noise in the five urban regions of Rasht.

Further investigation involved field measurements of noise levels, ventilation rates, and natural lighting in 45 residential units in Rasht. The evaluation revealed that 20% of the units had ventilation rates below the national standard value of 7.1 lit/(p.sec). While no significant correlation was observed between ventilation rates and SBS, there was a noteworthy relationship between SBS and poor air quality and high room temperature.

Sound pressure level measurements in the living rooms of residential units indicated that 75.5% of the units exceeded the permitted national daytime noise level (55 dBA). This high exposure to noise in residential units is regarded as a potential underlying cause for the elevated prevalence of SBS in Rasht compared to other studies, with this factor mainly attributed to motor vehicle transportation in the city. In this regard, implementing noise attenuation strategies including road-side barriers and installing double glazed windows on the buildings' façade, may be influential to reduce the noise level impacts in Rasht residential areas. Moreover, local planning authority needs to take account the national noise policies in permitting the construction of new building or changing the use of an existing building. Currently, the local governors do not consider the noise insulation compatibility of new buildings.

Furthermore, investigating the luminous condition in the living rooms of the 45 examined units revealed low or moderate lighting in 32% of the units during the day. Additionally, the average age of the buildings examined was 14 years, with no significant correlation found between building age and SBS. The interior surfaces of the buildings were predominantly covered with gypsum plaster, with no significant association found between the type of interior coverage, the symptoms of SBS, and the type of heating system during the cold seasons, at the $\alpha = 0.05$ level.

Nomenclature

BMR Body Mass Ratio
BRI Building Related Illness
CI Confidence Interval
CO Carbon Monoxide
CO_2 Carbon Dioxide
OR Odd Ratio
PM Particulate Matter
PPM Parts Per Million
RH Relative Humidity
SBS Sick Building Syndrome
SPL Sound Pressure Level
TWA Time Weighted Average
VOC Volatile Organic Compounds

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13690-024-01486-z.

Supplementary Material 1.
Supplementary Material 2.
Supplementary Material 3.
Supplementary Material 4.
Supplementary Material 5.

Acknowledgements
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author's contributions
This manuscript has only one author.

Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.
Informed consent was obtained from all individual participants included in this study.

Consent for publication
The authors of this manuscript declare their consent for publication.

Competing interests
The authors declare no competing interests.

Received: 4 July 2024 Accepted: 22 December 2024
Published online: 30 December 2024

References

1. Abdel-Salam MM. Indoor exposure of elderly to air pollutants in residential buildings in Alexandria, Egypt. Build Environ. 2022;219:109221.
2. Ahmadi Orkomi A, Mirchi M. Sick building syndrome symptoms among staff in Razi hospital of Chalous, Mazandaran province. IJHE. 2020;13(2):227-38. (In Persian).
3. Ainsworth B, Haskell W, Herrmann S, Meckes N, Bassett D, Tudor-Locke C. The compendium of physical activities tracking guide Arizona. Healthy Lifestyles Research Center. College of Nursing & Health Innovation, Arizona State University; 2011.
4. Andersson K, Stridh G. The use of standardized questionnaires in building-related illness (BRI) and sick building syndrome (SBS) survey. In: NATO/CCMS pilot study on indoor air quality. Oslo: National Institute of Occupational Health; 1991. p. 47–64.
5. Arikan İ, Tekin ÖF, Erbas O. Relationship between sick buildıng syndrome and indoor air quality among hospital staff. La Medicina Del Lavoro. 2018;109(6):435.
6. Burt T. Sick building syndrome: acoustic aspects. Indoor Built Environ. 1996;5(1):44–59.
7. Daniel WW, Cross CL. Biostatistics: a foundation for analysis in the health sciences. Wiley; 2018.
8. El-Batrawy OA. Indoor air quality and adverse health effects. World Appl Sci. 2013;25(1):163–9.
9. EPA. Exposure factors handbook. Washington DC: U.S. Environmental Protection Agency; 2011. EPA/600/R-09/052F.
10. Fisher RA. On the interpretation of χ 2 from contingency tables, and the calculation of P. J R Stat Soc. 1922;85(1):87–94.
11. Formulation of national building codes department (FNBCD). National Iranian Building Codes, part 14: mechanical equipment. Road, Housing & Urban Development Research Center, third edition, Tehran, Iran. 2017.
12. Gomzi M, Bobic J, Radosevic-Vidacek B, Macan J, Varnai VM, Milkovic-Kraus S, Kanceljak-Macan B. Sick building syndrome: psychological, somatic, and environmental determinants. Arch Environ Occup Health. 2007;62(3):147–55.
13. GPSIS. Management and planning organization of Guilan Province. Statistical information system of Guilan province. Guilan Province Stat Inform Syst. (In Persian). 2016. http://sdi.mpogl.ir/.
14. GPSIS. Management and planning organization of Guilan Province. Statistical information system of Guilan province. Guilan Province Stat Inform Syst. (In Persian). 2019. http://sdi.mpogl.ir/.
15. Guan H, Hu S, Liu G, Zhang L. The combined effects of temperature and noise on the comfort perceptions of young people with a normal body mass index. Sustain Cities Soc. 2020;54:101993.
16. Habil M, Massey DD, Taneja A. Exposure from particle and ionic contamination to children in schools of India. Atmos Pollut Res. 2015;6(4):719–25.
17. Hu X, Li N, Gu J, He Y, Yongga A. Lighting and thermal factors on human comfort, work performance, and sick building syndrome in the underground building environment. J Building Eng. 2023;79:107878.
18. Huo X, Sun Y, Hou J, Wang P, Kong X, Zhang Q, Sundell J. Sick building syndrome symptoms among young parents in Chinese homes. Build Environ. 2020;169:106283.
19. Jafari MJ, Khajevandi AA, Najarkola SAM, Yekaninejad MS, Pourhoseingholi MA, Omidi L, Kalantary S. Association of sick building syndrome with indoor air parameters. Tanaffos. 2015;14(1):55.
20. Joint FAO/WHO/UNU Expert Consultation. Human Energy requirements, Report of a Joint FAO/WHO/UNU Expert Consultation. Rome: Food and Agriculture Organization of the United Nations; 2001.
21. Kalender Smajlović S, Kukec A, Dovjak M. Association between sick building syndrome and indoor environmental quality in Slovenian hospitals: a cross-sectional study. Int J Environ Res Public Health. 2019;16(17):3224.

22. Keyvani S, Mohammadyan M, Mohamadi S, Etemadinezhad S. Sick building syndrome and its associating factors at a hospital in Kashan, Iran. Iran J Health Sci. 2017;5(2):19–24.
23. Lu C, Deng Q, Li Y, Sundell J, Norbäck D. Outdoor air pollution, meteorological conditions and indoor factors in dwellings in relation to sick building syndrome (SBS) among adults in China. Sci Total Environ. 2016;560:186–96.
24. Mentese S, Mirici NA, Elbir T, Palaz E, Mumcuoğlu DT, Cotuker O, Otkun MT. A long-term multi-parametric monitoring study: indoor air quality (IAQ) and the sources of the pollutants, prevalence of sick building syndrome (SBS) symptoms, and respiratory health indicators. Atmos Pollut Res. 2020;11(12):2270–81.
25. Miao Y, Ding Y. Indoor environmental quality in existing public buildings in China: measurement results and retrofitting priorities. Build Environ. 2020;185:107216.
26. Moazami TN, Sterud T. The combined effect of indoor climate and psychosocial stressors on subsequent headaches: A prospective study of the general working population in Norway. Indoor Built Environ. 2024;0(0). https://doi.org/10.1177/1420326X241290514.
27. Niven RM, Fletcher AM, Pickering CAC, Faragher EB, Potter IN, Booth WB, Jones TJ, Potter PDR. Building sickness syndrome in healthy and unhealthy buildings: an epidemiological and environmental assessment with cluster analysis. Occup Environ Med. 2000;57(9):627-34.
28. Orkomi AA, Bora KM. Traffic induced noise pollution prediction using Traffic Noise Model (TNM) in Rasht, Iran. Environ Eng Manag J. 2021;20(9):1415–23.
29. Ormandy D, Ezratty V. Thermal discomfort and health: protecting the susceptible from excess cold and excess heat in housing. Adv Build Energy Res. 2016;10(1):84–98.
30. Passarelli GR. Sick building syndrome: An overview to raise awareness. J Build Apprais. 2009;5:55-66.
31. Pearson K. On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling. New York: Springer; 1992. pp. 11–28.
32. Persily A, de Jonge L. Carbon dioxide generation rates for building occupants. Indoor Air. 2017;27(5):868–79. https://doi.org/10.1111/ina.12383.
33. Rashid M, Zimring C. A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings: problems and prospects of sharing evidence. Environ Behav. 2008;40(2):151–90.
34. Runeson R, Norbäck D, Stattin H. Symptoms and sense of coherence–a follow-up study of personnel from workplace buildings with indoor air problems. Int Arch Occup Environ Health. 2003;76:29–38.
35. Sadr MK, Nassiri P, Hosseini M, Monavari M, Gharagozlou A. Assessment of land use compatibility and noise pollution at Imam Khomeini International Airport. J Air Transp Manage. 2014;34:49–56.
36. Sahlberg B, Mi YH, Norbäck D. Indoor environment in dwellings, asthma, allergies, and sick building syndrome in the Swedish population: a longitudinal cohort study from 1989 to 1997. Int Arch Occup Environ Health. 2009;82:1211–8. https://doi.org/10.1007/s00420-009-0444-3.
37. Saijo Y, Nakagi Y, Ito T, Sugioka Y, Endo H, Yoshida T. Relation of dampness to sick building syndrome in Japanese public apartment houses. Environ Health Prev Med. 2009;14(1):26–35.
38. Sarkhosh M, Najafpoor AA, Alidadi H, Shamsara J, Amiri H, Andrea T, Kariminejad F. Indoor air quality associations with sick building syndrome: an application of decision tree technology. Build Environ. 2021;188:107446.
39. Shao Z, Bi J, Yang J, Ma Z. Indoor PM2. 5, home environmental factors and lifestyles are related to sick building syndrome among residents in Nanjing, China. Build Environ. 2023;235:110204.
40. Shrubsole C, Taylor J, Das P, Hamilton IG, Oikonomou E, Davies M. Impacts of energy efficiency retrofitting measures on indoor PM2.5 concentrations across different income groups in England: a modelling study. Adv Build Energy Res. 2016;10(1):69–83.
41. Siu-Yu Lau S, Gou Z, Li FM. Users' perceptions of domestic windows in Hong Kong: challenging daylighting-based design regulations. J Build Apprais. 2010;6:81–93.
42. Sun Y, Hou J, Cheng R, Sheng Y, Zhang X, Sundell J. Indoor air quality, ventilation and their associations with sick building syndrome in Chinese homes. Energy Build. 2019;197:112–9.
43. Sundell J. Reflections on the history of indoor air science, focusing on the last 50 years. Indoor Air. 2017;27(4):708–24.
44. Suzuki N, Nakayama Y, Nakaoka H, Takaguchi K, Tsumura K, Hanazato M, Mori C. Risk factors for the onset of sick building syndrome: a cross-sectional survey of housing and health in Japan. Build Environ. 2021;202:107976.
45. Takigawa T, Saijo Y, Morimoto K, Nakayama K, Shibata E, Tanaka M, Kishi R. A longitudinal study of aldehydes and volatile organic compounds associated with subjective symptoms related to sick building syndrome in new dwellings in Japan. Sci Total Environ. 2012;417:61–7.
46. Tham KW. Indoor air quality and its effects on humans—a review of challenges and developments in the last 30 years. Energy Build. 2016;130:637–50.
47. Witterseh T, Wyon DP, Clausen G. The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work. Indoor Air. 2004;14(8):30–40.
48. Wright JD, Wang CY. Trends in intake of energy and macronutrients in adults from 1999–2000 through 2007–2008. NCHS Data Brief. 2010;49:1–8.
49. Xue P, Mak CM, Cheung HD. The effects of daylighting and human behavior on luminous comfort in residential buildings: a questionnaire survey. Build Environ. 2014;81:51–9.
50. Zhang X, Sahlberg B, Wieslander G, Janson C, Gislason T, Norback D. Dampness and moulds in workplace buildings: associations with incidence and remission of sick building syndrome (SBS) and biomarkers of inflammation in a 10 year follow-up study. Sci Total Environ. 2012;430:75–81.

Publisher's Note