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Perceived Air Quality, Thermal Comfort and Health: A Survey of Social Housing Residents in Kazakhstan

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Abstract: Kazakhstan is in Central Asia and is the ninth-largest country in the world. Some socially vulnerable segments of the Kazakh population residing in subsidised social housing have experienced a range of problems due to the low quality of housing construction and its planning. Poor indoor environmental conditions in social housing contribute to occupants' comfort, health, and general well-being. This study assessed social housing residents' health and quality of life, focusing on their perceived indoor air quality and thermal comfort satisfaction. A cross-sectional survey in Kazakhstan was conducted to test the effects of environmental factors on social housing residents' health and satisfaction. Four hundred thirty-one responses were analysed, and the SF12v2 questionnaire was used to measure the health-related quality of life. Multiple regression analysis showed that air quality negatively predicted the respondents' physical (PCS) and mental (MCS) health. In addition, age, smoking, and employment status had a significantly negative effect on PCS, while education level had a predictive positive effect. Thermal conditions negatively predicted only MCS, as well as alcohol consumption. Next, the air-conditioning control factor had a negative effect. In contrast, low air circulation, low humidity, high solar gain, temperature imbalance, duration of the residence and alcohol consumption had a significantly positive effect on overall satisfaction with the temperature. The odour sources from tobacco, furniture and external sources were predictors of respondents' overall air quality satisfaction, along with the duration of the residence, alcohol consumption and smoking status.

Keywords: social housing; indoor air quality; indoor thermal quality; perceived indoor environment; SF12v2; public health; health and quality of life; HQoL; Kazakhstan; Central Asia

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1. Introduction

The unprecedented levels of urbanisation in many Central Asian countries led to a growth in demand for housing in the city centres and peripheries, reducing housing's affordability for low-income sectors of society. Kazakhstan is situated in Central Asia and is the world's largest landlocked country. Its vast territory spans across both Europe and Asia, featuring a diverse range of geographical and climatic features [1]. The focus on extractive industries in Kazakhstan's economic development resulted in higher rates of urbanisation than the rest of the region, from 43.7% in 1959 [2,3] to 59.5% in 2022 [4]. Rapid urbanisation, climatic conditions and Kazakhstan's unique geographical location, characterised by extreme winters and hot summers, as well as vast steppes to mountain ranges, pose additional challenges to sustainable urban development and housing policy [5].

As the leading economy in Central Asia, the development of the oil and gas sector has allowed Kazakhstan's economy to join the ranks of upper-middle-income countries [6]. Despite governmental strategies since the 1990s prioritising economic diversification, Kazakhstan remains afflicted by the "resource curse", adversely influencing poverty levels and widening income inequality [7]. The country also exhibits significant socio-economic inequalities, underscored by significant disparities in socio-economic development across different inter-regions [8]. This economic disparity is reflected in the housing market, with a recent study showing that no region in Kazakhstan has complete housing affordability, with housing prices not corresponding to the incomes of its citizens [9]. The government's housing policy, aimed at increasing the availability of affordable housing through various economic development programs, such as the 'Nurly Zher' ('Bright Path') stimulus, has sought to address these issues by promoting the construction of affordable housing units and providing mortgage subsidies for eligible citizens [10]. However, challenges remain in terms of the quality of affordable housing and the accessibility of these programs to the most vulnerable populations.

In the nineteenth century, Engels [11] gave a detailed description of the complex housing situation of the working class, typically resulting in low-income households being pushed out of the centre of a town towards the poor-quality housing on the city's outskirts. Even though the social housing sector evolved very differently from one country to another [12], Engel's prescient analysis of the housing system can still be traced to Kazakhstan's affordable housing policy. Kazakhstan's major urban centres have high homeownership rates, mainly due to the legacies of the Soviet Union's housing policies [13]. The high cost of living in cities leads to the exclusion of lower-income households [14], not only from the city centres but even from the city peripheries [15], especially following the two waves of migration from Russia since 2022 [16].

The total volume of the housing stock in Kazakhstan has increased by 25% in the last decade, with the state owning only a tiny share, at 2.24% [9]. The imbalance in the levels of existing socially vulnerable segments of the population and the provision of subsidised housing has been aggravated by the accumulated problems in the quality of construction and its planning [17]. Urban Forum Kazakhstan [18] noted that disorderly and unplanned social housing development leads to low-quality, outskirt-located, uncomfortable, and segregated districts. Segregated low-income populations are subjected to a disproportionate and uneven distribution of environmental toxins in their air, water, and housing, which might negatively impact their physical health and psychosocial and behavioural well-being, which can harm their mental health [19,20].

Numerous cases have acknowledged the relationship between poor indoor environmental conditions in social housing and adverse health consequences [21]. It has been observed [22] that social housing had significantly higher concentrations of air pollutants, inadequate ventilation and reported mold compared to green homes, suggesting that multilevel housing interventions can improve long-term resident health. Previous research has found that various physical aspects defining the living environment, such as indoor air quality and thermal comfort, contribute to social housing occupants' lower comfort, health and general well-being [23]. Low-income households in Australian social housing have experienced summer overheating and winter underheating [24], with more than half of the surveyed people reporting health problems like respiratory diseases and allergies and around 30% reporting mental health problems [25].

Recent research based on Kazakhstan's general population's subjective perception of well-being found that low monthly income was one of the strongest negative predictors of poor physical and mental health [26]. In addition, considerable inequalities in self-rated health related to material deprivation were found in a Kazakhstani population of mature people aged 45+ [27]. The findings suggest that the prevention of a deterioration of subjective well-being should be aimed at susceptible populations with lower socio-economic status. Given that the population of Kazakhstan is more vulnerable to adverse health outcomes due to living conditions and low socio-economic status [28], studying the indoor environmental quality in these environments becomes imperative for assessing built environments, identifying policy implications, and evaluating healthy homes for improved living standards. This study aimed to assess social housing residents' health and quality of life, focusing on their perceived thermal comfort and indoor air quality satisfaction, in the Zerdely social housing district of the city of Almaty, Kazakhstan.

2. Materials and Methods

2.1. Research Design

To study the relationship between perceived indoor environmental quality (IEQ) and its effect on social housing occupants' health-related quality of life (HQoL), a self-administered paper questionnaire was designed based on the IEQ literature and SF12v2, which is a 12-item health survey that is widely used to assess people's health-related quality of life [29]. The questionnaire comprised four parts and received ethical approval from the University of Liverpool's Ethics Committee (approval number V02050722).

The design of the questionnaire was aimed at identifying the most direct correlations between IEQ and health outcomes within the specific research objectives and the characteristics of the target population. The first part of the questionnaire collected a respondent's demographic and background information, such as age, gender, employment status (Emp_stat), educational level (Edu_stat) and personal habits that may affect health, like smoking (Smo_stat) and alcohol drinking (Alc_stat) status. In the second part, respondents described how long they had lived in their residence (L_dura), floor level (H_floor), the number of thermal controls and adjustment solutions (Num_Tcontrol), overall satisfaction with temperature (OS_T), and the number of sources to cause thermal discomfort (Num_Tdis). The third part of the questionnaire asked about overall satisfaction with indoor air quality (OS_AQ) and sources of dissatisfaction, focusing on a number of issues, if any, that caused odour problems (Num_Odo). The satisfaction ratings were evaluated on a 7-point Likert scale, with the dissatisfied answers prompting follow-up questions to make the occupants evaluate their sources of dissatisfaction. Finally, the last part of the questionnaire included the SF-12v2 Health Survey (SF12), with the license agreement from QualityMetric Incorporated, measuring eight health domains in physical (PF) and social functioning (SF), bodily pain (BP), general health (GH), vitality (VT), role limitations due to physical (RP) and emotional (RE) health problems, and mental health (MH), with each domain contributing to the physical (PCS) and mental (MCS) component scores. The SF12v2 Health Survey has been widely validated for predicting a population's mental and physical health [30,31], including low socio-economic populations [32].

To enrich an understanding of the factors influencing indoor air quality and thermal comfort satisfaction, this study focused on variables directly related to the resident's immediate living environment and perceptions of their health. This focus was in response to a strategic decision to prioritise the investigation of tangible and perceivable aspects of IEQ that residents could reliably report. While recognising the potential influence of broader socio-economic factors, such as household income and housing maintenance status, on perceptions of air quality, this study opted to focus its analysis on variables that offered the most direct insight into the relationship between IEQ and health outcomes within the specific context of the Zerdely social housing district.

The research design is shown in Figure 1. The independent variables consist of perceived thermal and air qualities of the indoor climate satisfaction levels and actions taken to alter their interior environment. The covariates were included in terms of two dimensions: housing and living and demographic and socio-economic conditions. The apartment's floor level (H_floor) and the length of occupation (L_dura) were considered under the housing and living conditions, and the essential details about the residents and their behaviours were considered under demographic and socio-economic characteristics. The primary dependent variable was the residents' self-rated physical (PCS) and mental (MCS) health components, as well as overall satisfaction with thermal (OS_T) and air quality (OS_AQ).

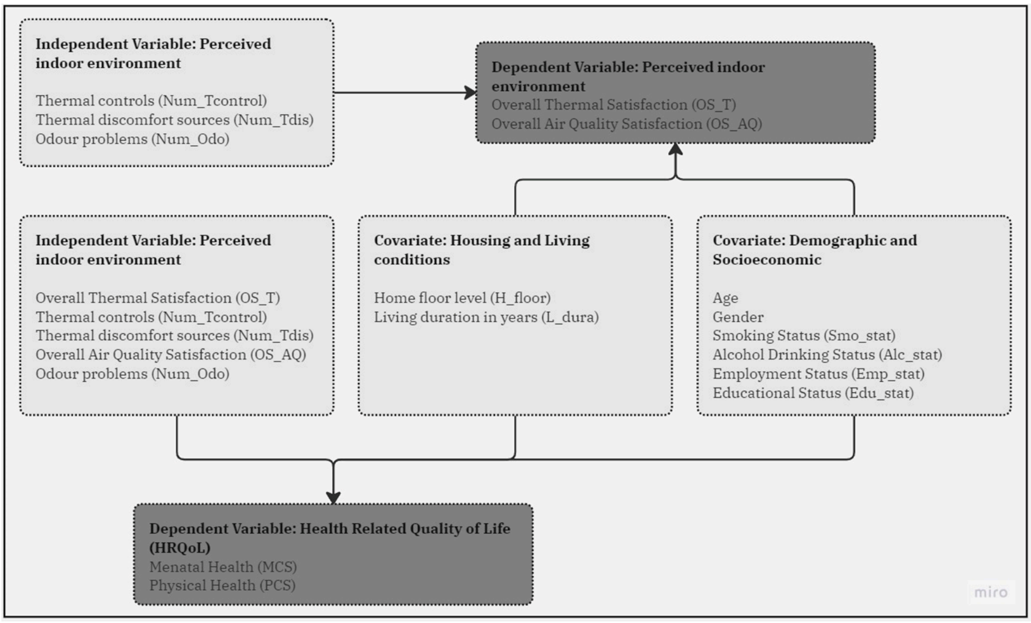

Figure 1. Research design: independent, covariate, and dependent variables.

The survey was conducted among the adult population residing in a social housing micro-district, Zerdely, in Almaty, Kazakhstan, from the 1st to the 10th of September 2022. The average daily temperatures ranged from +20.8 °C to +26.4 °C. The relative humidity levels varied across these days, with the lowest recorded on the 2nd of September (28%) and the highest on the 9th of September (42%) [33]. Wind speed remained low throughout the survey period, ranging from 1 to 2 m/s, indicating calm to light air movement [33]. Low wind speeds might result in less ventilation and air exchange in naturally ventilated indoor spaces, potentially affecting the indoor environment's perceived comfort. Overall, the weather conditions during the survey period were conducive to evaluating residents' perceptions of indoor environmental quality without extreme weather events impacting the results. However, the warm temperatures and varying relative humidity levels highlight the importance of considering thermal comfort and air quality as critical components of perceived IEQ in social housing studies.

The micro-district of Zerdely was selected because it was built under the state programme 'Affordable Housing 2020', making its residents particularly suitable for this study. Over the years, these residents have had time to adapt to the long-term effects of their housing conditions on their health and well-being [34,35]. This temporal aspect is important because it allows for an examination of more sustained impacts rather than transient adjustments, which provides an opportunity to further understand the relationship between housing quality and resident health in a defined community. Additionally, the study might offer findings that may be applicable to similar climatic and residential settings across the country but not necessarily generalisable to all Kazakh people or residents of other regions without further study.

The Zerdely micro-district consists of one hundred and twelve apartment buildings of three different heights (four, five and nine-storey) located on a plot of approximately 0.44 km^2 in area. By focusing the survey here, this study aimed to capture a comprehensive snapshot of the lived experiences of those dwelling in social housing, against the backdrop of Kazakhstan's urban and socio-economic landscape, as detailed in the Introduction. Figure 2 shows views of the surveyed housing.

Figure 2. Views of the surveyed social housing complex, Almaty, Kazakhstan.

Participants aged 18 years or older were considered eligible to participate in this study. To ensure the survey reached a representative cross-section of the Zerdely population, a total of fifteen trained interviewers from the Department of Pharmaceutical Technology of Asfendiyarov Kazakh National Medical University were used. These interviewers administered the face-to-face questionnaire survey in the respondents' approved language version, using Kazakh or Russian language formats, prior to obtaining the signature on the participant consent form to ensure inclusivity and comprehensiveness in data collection. An introductory script was used to introduce the survey to each resident. The survey interviewers went door-to-door in pairs and administered the survey using a paper questionnaire distributed throughout the neighbourhood to cover apartments with different plan layouts, exteriors and floor heights.

2.2. Data Analysis

Several statistical models were implemented using the IBM® SPSS® Statistics 29.0 program [36] to analyse the collected data in this study. Descriptive statistics were used to display quantitative measures and the frequency distributions of the social housing residents' socio-economic, demographic and housing characteristics. Next, Pearson correlation analyses were performed to test the correlations between independent and dependent variables. A series of linear regressions were used to predict the value of PCS, MCS, and overall thermal and air quality satisfaction based on the value of the independent variable.

Three regression models were conducted, with Model 1 testing only the predicted influence of the five environmental variables. Model 2 showed how the influence of these five factors could be adjusted by respondents' duration of residence and floor height. Finally, Model 3 tested the adjustment of respondents' six background characteristics for the influence of Model 2, which included environmental and housing conditions.

3. Results

3.1. Respondent Characteristics and Indoor Environment Conditions

In this study, a total number of 431 valid questionnaires (out of 450) were included, with a response rate of 95.7%. Table 1 presents the baseline demographic descriptors for the social housing residents in the Zerdely micro-district. Overall, the slightly overrepresented categories include females, at 57.5%, and the housing group aged over 41 years and older, at 23.4%. This pattern aligns with findings in similar socio-economic settings, indicating specific lifestyle choices prevalent among social housing residents [37]. Notably, a relatively high percentage, approximately 67%, stated that they do not smoke or drink alcoholic beverages. 42.2% were employed full-time, and 1.6% stated that they could not work. The average length of residence was 4.22 years (SD = 3.16).

Table 1. Descriptive statistics of respondent's characteristics.

Variable	Item	n	Percentage
Gender	Male	178	41.3
	Female	248	57.5
	Prefer not to disclose	5	1.2
Age	≤20	60	13.9
	21–25	69	16.0
	26–30	64	14.8
	31–35	74	17.2
	36–40	63	14.6
	41≥	101	23.4
Smoking status	- Never smoked	288	66.8
	- Used to smoked	71	16.5
	- Smoke occasionally	38	8.8
	- Smoke less than 5 cigarettes daily	13	3.0
	- Smoke 5–15 cigarettes daily	13	3.0
	- Smoke more than 15 cigarettes daily	6	1.4
	- Smoke tobacco products other than cigarettes daily	2	0.5
Alcohol Consumption Status	Never	288	66.8
	Monthly or less	115	26.7
	2–4 times a month	17	3.9
	2–3 times per week	4	0.9
	≥4 times per week	7	1.6
Employment Status	Employed full-time	182	42.2
	Employed part-time	27	6.3
	Self-employed/freelance	45	10.4
	Studying	61	14.2
	Retired	35	8.1
	Unemployed	44	10.2
	Not able to work	7	1.6
	Prefer not to say	30	7.0
Educational Level	Primary school	3	0.7
	Secondary school	82	19.0
	Higher secondary education or technical and vocational education	139	32.3
	College or University	128	29.7
	Postgraduate degree	35	8.1
	Prefer not to say	44	10.2

The examination of smoking and drinking habits among the participants reflects the lifestyle trends within the Zerdely micro-district's social housing community. These trends are consistent with behaviours observed in comparable socio-economic environments. Typically, abstention from alcohol and moderate consumption is more common in neighbourhoods of lower socio-economic status [38,39]. While higher levels of neighbourhood deprivation have been linked to increased smoking rates [40], this study found that the proportion of individuals who smoked aligned with the national trend in Kazakhstan, where the overall prevalence of tobacco use slightly decreased from 22.9% in 2014 to 21.5% in 2019 [41,42].

Table 2 provides descriptive statistics on the housing features. In this study, 72.9% of the respondents were residing from the first to fourth floors, reflecting the fact that out of 112 apartment buildings in the micro-district, only 32 were nine stories high. The multiple response frequency analysis of the personally adjusted indoor control variables showed that most residents adjusted window blinds or shades (81.9%), and less than half of the respondents (40.5%) owned air conditioning units. The window operability by residents was low, at 31.4%, with 14.7% owning a portable fan. Furthermore, 34.4% of the respondents regulated the degree of heat supply to the radiator, indicating active engagement with their living environment to maintain comfort.

Table 2. Characteristics of built environment conditions in surveyed social housing.

Variable	Item	% of Respondents (n = 431)
Responses by floor level	1–4	72.9
	≥9	27.1
Frequency of personally adjusted items	None of these or the other	0.2
	1 item	32.3
	2 items	35.5
	3 items	16
	4 items	12.5
	5 items	3.2
	7 items	0.2

In contrast, residents in private housing often display a broader range of socio-economic diversity, which can influence lifestyle choices, access to amenities, and health behaviours differently [43,44]. The disparities in housing quality and access to services between social and private housing underscore the importance of considering these differences when evaluating health outcomes and IEQ.

3.2. Correlation Analysis: Key Variables

Table 3 presents the Pearson correlation analyses that were performed to assess the relationship between six demographic and socio-economic variables, two housing and living conditions items, five environmental variables, two overall satisfaction items, and two health measures. The mean value of the physical health scores (PCS) was 52.22 ± 6.28, and the mean score for mental health (MCS) was 50.14 ± 9.97.

The correlation analysis showed a significant negative correlation ($p < 0.01$) between overall air quality and thermal satisfaction, with both PCS ($r = -0.250$; $r = -0.126$) and MCS ($r = -0.293$; $r = -0.192$) emphasising the importance of IEQ for residents' health. This underscores the critical need for interventions aimed at enhancing air quality and thermal comfort within this setting to improve health outcomes. Additionally, alcohol consumption was negatively correlated ($p < 0.01$) with PCS ($r = -0.145$) and MCS ($r = -0.127$), suggesting that higher alcohol consumption may be associated with poorer health. Conversely, it was positively correlated with overall thermal ($r = 0.173$) and air quality ($r = 0.130$) satisfaction, indicating that individuals with higher alcohol consumption might have differing perceptions or use of alcohol as a coping mechanism for environmental dissatisfaction.

Table 3. Correlation analysis between 15 variables, including demographic and socio-economic, housing and environmental conditions, and health status (n = 431).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	1														
Gender	0.085	1													
Smo_stat	0.123 *	−0.404 **	1												
Alc_stat	0.163 **	−0.217 **	0.495 **	1											
Emp_stat	0.043	0.160 **	−0.014	0.018	1										
Edu_stat	0.083	0.067	0.005	0.074	0.171 **	1									
L_dura	0.225 **	0.064	−0.033	0.074	−0.007	−0.069	1								
H_floor	−0.034	−0.040	0.008	−0.041	0.007	0.069	−0.042	1							
Num_Tcontrol	−0.102 *	0.067	0.030	−0.044	−0.075	−0.013	−0.002	0.041	1						
OS_T	0.068	−0.040	0.068	0.173 **	0.025	−0.039	0.105 *	0.012	−0.029	1					
Num_Tdis	0.040	−0.030	0.099 *	0.069	−0.030	0.017	0.022	0.078	0.260 **	0.156 **	1				
OS_AQ	0.066	0.047	−0.067	0.130 **	−0.021	0.014	0.155 **	−0.003	−0.045	0.430 **	0.185 **	1			
Num_Odo	−0.087	0.005	−0.009	−0.012	−0.054	0.012	−0.082	0.027	0.197 **	−0.132 **	0.204 **	0.032	1		
PCS	−0.234 **	0.028	−0.184 **	−0.145 **	−0.080	0.039	−0.067	−0.004	0.008	−0.126 **	−0.100 *	−0.250 **	0.043	1	
MCS	0.025	−0.028	−0.019	−0.127 **	0.037	0.039	−0.103 *	0.001	0.019	−0.192 **	−0.007	−0.293 **	−0.032	0.165 **	1

Pearson correlation significant: * $p < 0.05$, ** $p < 0.01$.

There was a statistically significant negative correlation between PCS and the number of sources to cause thermal discomfort ($r = -0.100$, $p < 0.05$), age ($r = -0.234$, $p < 0.01$), and smoking status ($r = -0.184$, $p < 0.01$), highlighting the adverse effects of ageing and smoking on physical health. Furthermore, a significant negative correlation ($p < 0.05$) was found between the duration of the residence and mental health component ($r = -0.103$), and a positive correlation with overall thermal ($r = 0.105$, $p < 0.05$) and air quality ($r = 0.155$, $p < 0.01$). Overall thermal satisfaction was strongly correlated with overall air quality satisfaction ($r = 0.430$, $p < 0.01$), signifying that improvements in one aspect of the indoor environment might positively influence perceptions of the other, advocating for a holistic approach to environmental improvements. Next, overall thermal satisfaction negatively correlated with several issues that caused odour problems ($r = -0.132$, $p < 0.01$), suggesting the importance of addressing these problems. Lastly, the floor height level was not statistically significantly correlated with any other tested variables across all of the combinations.

3.3. Effect of Environmental Satisfaction (Thermal and Air Quality) on Physical Health (PCS) and Mental Health (MCS)

Table 4 presents the results of the three regression models that were performed to understand the effect of the independent variables on the respondents' PCS. In the linear regression models, *B* indicates the level of influence on the dependent variable by the independent variable, and *SE* means standard error.

Table 4. Multiple regression analysis with PCS as outcome variable.

Variable	Model 1		Model 2		Model 3	
	B	**SE**	**B**	**SE**	**B**	**SE**
Constant	54.478 ***	0.918	54.679 ***	1.096	58.250 ***	1.759
Num_Tcontrol	0.012	0.271	0.015	0.272	−0.125	0.265
OS_T	−0.016	0.187	−0.014	0.188	0.094	0.182
Num_Tdis	−0.505	0.369	−0.503	0.370	−0.273	0.358
OS_AQ	−0.813 ***	0.181	−0.801 ***	0.183	−0.896 ***	0.178
Num_Odo	0.437	0.338	0.423	0.340	0.302	0.327
L_dura			−0.048	0.096	0.039	0.095
H_floor			−0.007	0.141	−0.038	0.136
Age					−0.724 ***	0.172
Gender					−0.064	0.578
Smo_stat					−0.953 ***	0.305
Alc_stat					−0.005	0.445
Emp_stat					−0.259 **	0.129
Edu_stat					0.418 *	0.243
R^2	0.069		0.070		0.156	
ΔR^2			0.001		0.086	

Significant: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Model 1 established that overall air quality satisfaction statistically significantly predicts respondents' PCS ($B = -0.813$, $p < 0.01$) with an R^2 of 0.069 ($p < 0.01$). This indicates that as satisfaction with air quality decreases, PCS worsens. When housing conditions were entered into the regression Model 2, the air quality environmental variable still significantly predicted the physical health component ($B = -0.801$, $p < 0.01$); however, the increase in R^2 was not significant ($p > 0.05$). After adding the demographic and socio-economic status and housing variables, Model 3 showed the same results as Models 1 and 2 for the overall air quality satisfaction variable ($B = -0.896$, $p < 0.01$), as well as a predicting role of age ($B = -0.724$, $p < 0.01$), smoking habit ($B = -0.953$, $p < 0.01$), employment status ($B = -0.259$, $p < 0.05$) and educational level ($B = 0.418$, $p < 0.1$) on PCS with an R^2 value of 0.156 ($p < 0.01$).

Table 5 presents the results of three regression models that were examined to understand the effect of the independent variables on the respondents' mental health (MCS) in a social housing context.

Table 5. Multiple regression analysis with MCS as outcome variable.

Variable	Model 1		Model 2		Model 3	
	B	SE	B	SE	B	SE
Constant	54.843 ***	1.436	55.632 ***	1.712	56.129 ***	2.859
Num_Tcontrol	−0.034	0.424	−0.022	0.424	0.075	0.430
OS_T	−0.543 *	0.293	−0.532 *	0.293	−0.470	0.296
Num_Tdis	0.789	0.576	0.794	0.578	0.777	0.581
OS_AQ	−1.430 ***	0.283	−1.383 ***	0.285	−1.351 ***	0.289
Num_Odo	−0.539	0.528	−0.596	0.531	−0.531	0.531
L_dura			−0.193	0.150	−0.212	0.155
H_floor			−0.022	0.221	−0.055	0.221
Age					0.427	0.280
Gender					−1.065	0.938
Smo_stat					−0.203	0.496
Alc_stat					−1.282 *	0.723
Emp_stat					0.154	0.210
Edu_stat					0.286	0.394
R^2	0.097		0.100		0.116	
ΔR^2			0.004		0.016	

Significant: * $p < 0.1$, *** $p < 0.01$.

Model 1 focuses on the impact of overall air quality satisfaction on MCS, revealing a significant negative relationship ($B = -1.430$, $p < 0.01$), with an R^2 of 0.097 ($p < 0.01$). This indicates that lower satisfaction with air quality is associated with poorer mental health outcomes. With the inclusion of housing condition variables in Model 2, overall satisfaction with the thermal environment ($B = -0.532$, $p < 0.1$) and air quality ($B = -1.383$, $p < 0.01$) significantly predicted mental health. After including demographic and socioeconomic variables in Model 3, the effects of air quality ($B = -1.351$, $p < 0.01$) and alcohol consumption status ($B = -1.282$, $p < 0.1$) significantly predicted mental health scores. However, factors such as thermal environment satisfaction did not significantly affect MCS ($p > 0.05$). Additionally, there were no significant differences among the R^2 values of Models 2 and 3 ($p > 0.05$).

3.4. Prediction of Environmental Satisfaction (Thermal and Air Quality)

Table 6 presents the results of three regression models that predict the effect of various independent variables on overall thermal satisfaction as an outcome variable.

Model 1 indicated that personally adjusting a room air conditioning unit ($B = -0.792$, $p < 0.01$) and none of the provided number of control variables ($B = 1.649$, $p < 0.01$) in the respondents' indoor environment significantly predicted the overall thermal satisfaction levels, with an R^2 value of 0.082 ($p < 0.01$). With the inclusion of the housing variables in Model 2, the predicting roles of personally controlling the room air conditioning unit ($B = -0.861$, $p < 0.01$), none of the provided variables ($B = 1.471$, $p < 0.05$), and the duration of the occupancy ($B = 0.047$, $p < 0.1$) were significant. In Model 3, after adding the socioeconomic and demographic factors, the predicting role of the room air conditioning unit ($B = -0.861$, $p < 0.01$), none of the provided variables ($B = 1.471$, $p < 0.05$), and alcohol consumption ($B = 0.379$, $p < 0.01$) had a significant effect on overall thermal satisfaction. However, the other room control variables and housing conditions had no significant effect on overall temperature satisfaction. Additionally, the increases in R^2 values in Models 2 and 3 were not statistically significant ($p > 0.05$).

Table 6. Multiple regression analysis with thermal control factors as part of the independent variables and overall satisfaction with temperature as the outcome variable.

Variable	**Model 1**		**Model 2**		**Model 3**	
	B	**SE**	**B**	**SE**	**B**	**SE**
Constant	2.462 ***	0.240	2.209 ***	0.308	1.770 ***	0.510
C_blinds	0.067	0.236	−0.110	0.334	−0.120	0.336
C_AC	−0.792 ***	0.173	−0.889 ***	0.267	−0.861 ***	0.271
C_por_heater	0.258	0.343	0.098	0.421	0.092	0.420
C_fix_heater	0.285	0.185	0.153	0.276	0.127	0.278
C_airvent	0.238	0.447	0.025	0.521	−0.024	0.522
C_fan	0.194	0.252	0.075	0.321	0.062	0.322
C_thermostat	0.595	0.434	0.411	0.504	0.209	0.507
C_open_win	−0.030	0.109	−0.060	0.129	−0.064	0.129
C_none	1.649 ***	0.623	1.482 **	0.651	1.471 **	0.670
C_other	−1.141	1.012	−1.368	1.037	−1.374	1.034
L_dura			0.047 *	0.027	0.037	0.028
H_floor			0.015	0.040	0.023	0.040
Num_Tcontrol			0.130	0.218	0.164	0.219
Age					0.028	0.052
Gender					−0.019	0.172
Smo_stat					−0.056	0.089
Alc_stat					0.379 ***	0.129
Emp_stat					0.006	0.038
Edu_stat					−0.040	0.072
R^2	0.082		0.090		0.112	
ΔR^2			0.008		0.022	

Significant: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. C_blinds: window blinds or shades; C_AC: room air-conditioning unit; C_por_heater: portable heater; C_fix_heater: permanent heater; C_airvent: adjustable air vent in wall or ceiling; C_fan: portable fan; C_thermostat: thermostat; C_open_win: openable window; C_none: none of above; C_other: specific answer.

Table 7 presents the results of three regression models that were performed to understand the impact of various sources of discomfort on the respondents' overall thermal satisfaction as the outcome variable.

Table 7. Multiple regression analysis with sources of discomfort as part of the independent variables and overall satisfaction with temperature as the outcome variable.

Variable	**Model 1**		**Model 2**		**Model 3**	
	B	**SE**	**B**	**SE**	**B**	**SE**
Constant	1.761 ***	0.200	1.489 ***	0.270	1.211 **	0.499
D_hum_high	0.104	0.360	0.185	0.603	0.173	0.603
D_hum_low	0.577 ***	0.205	0.632	0.536	0.624	0.538
D_air_high	0.467	0.339	0.545	0.593	0.375	0.593
D_air_low	0.980 ***	0.357	1.103 *	0.600	1.077 *	0.599
D_solargain	0.463 **	0.188	0.501	0.519	0.447	0.519
D_dra_window	−0.130	0.201	−0.103	0.542	−0.1	0.541
D_dra_vents	0.306	0.589	0.328	0.777	0.293	0.777
D_T_imbal	1.320 ***	0.347	1.338 **	0.612	1.217 **	0.614
D_T_stat	0.369	0.324	0.52	0.615	0.44	0.616
D_stra	0.258	0.299	0.327	0.576	0.291	0.579
D_other	0.439	0.329	0.429	0.329	0.476	0.33
Occu_years			0.066 **	0.027	0.054 *	0.028
Floor			0.005	0.040	0.012	0.04
Num_T_dis			−0.071	0.527	−0.032	0.527
Employ_status					0.038	0.038
Drinking					0.343 **	0.129
Edu_status					−0.066	0.072
Gender					−0.062	0.171
Age					0.03	0.051
Smoking					−0.05	0.09
R^2	0.078		0.091		0.113	
ΔR^2			0.013		0.022	

Significant: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. D_hum_high: humidity too high; D_hum_low: humidity too low; D_air_high: air movement too high; D_air_low: air movement too low; D_solargain: incoming sun; D_dra_window: drafts from window; D_dra_vents: drafts from vents; D_T_imbal: my area is hotter/colder than other areas; D_T_stat: thermostat is adjusted by other people; D_stra: hot/cold surrounding surfaces; D_other: specific answer.

Model 1 established that low relative humidity ($B = 0.577$, $p < 0.01$), low air movement ($B = 0.980$, $p < 0.01$), solar gain ($B = 0.463$, $p < 0.05$) and the indoor temperature imbalance ($B = 1.320$, $p < 0.01$) statistically significantly predicted overall thermal satisfaction, with an R^2 of 0.078 ($p < 0.01$). With the inclusion of housing condition variables in Model 2, the indoor temperature imbalance ($B = 1.338$, $p < 0.05$) and low air movement ($B = 1.103$, $p < 0.1$) continued to significantly predict thermal satisfaction. The duration of the residence ($B = 0.066$, $p < 0.05$) also emerged as a significant predictor, indicating that longer residency was associated with higher thermal satisfaction. In Model 3, after adding demographic and socio-economic variables, the effects of the indoor temperature imbalance ($B = 1.217$, $p < 0.05$), low air movement ($B = 1.077$, $p < 0.1$), the duration of the residence ($B = 0.054$, $p < 0.1$) and alcohol consumption ($B = 0.343$, $p < 0.05$) significantly predicted overall thermal satisfaction. Additionally, there were no significant differences among the R^2 values of Models 2 and 3 ($p > 0.05$).

Table 8 presents the results of three regression models that predicted the effect of various independent variables on overall air quality satisfaction as an outcome variable.

Table 8. Multiple regression analysis with overall satisfaction with air quality as outcome variable.

Variable	Model 1		Model 2		Model 3	
	B	SE	B	SE	B	SE
Constant	1.917 ***	0.218	1.616 ***	0.284	1.209 **	0.506
OD_tob	0.366 *	0.192	0.394	0.516	0.656	0.517
OD_equip	−0.260	0.288	−0.254	0.590	−0.069	0.587
OD_food	−0.349	0.221	−0.276	0.526	−0.046	0.530
OD_furn	−1.519 **	0.620	−1.369	0.829	−1.065	0.824
OD_perfu	0.847	0.812	1.025	0.937	1.504	0.937
OD_produ	0.259	0.541	0.310	0.712	0.522	0.709
OD_out	0.894 ***	0.208	0.866 *	0.498	1.057 **	0.498
OD_other	0.503 *	0.269	0.402	0.272	0.427	0.271
L_dura			0.067 **	0.028	0.051 *	0.029
H_floor			0.017	0.041	0.029	0.041
Num_Odo			−0.030	0.492	−0.253	0.492
Age					0.036	0.051
Gender					0.094	0.172
Smo_stat					−0.251 ***	0.090
Alc_stat					0.484 ***	0.132
Emp_stat					−0.014	0.038
Edu_stat					−0.023	0.073
R^2	0.081		0.093		0.129	
ΔR^2			0.012		0.036	

Significant: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. OD_tob: tobacco smoke; OD_equip: equipment; OD_food: food; OD_furn: carpet or furniture; OD_perfu: perfume; OD_produ: cleaning products; OD_out: outside sources (car, exhaust, smog); OD_other: specific sources (none of the above).

Model 1 indicated that odour problems that contributed to respondents' dissatisfaction with the indoor air quality, particularly from tobacco smoke ($B = 0.366$, $p < 0.1$), external sources ($B = 0.894$, $p < 0.01$), home furnishings ($B = -1.519$, $p < 0.05$) and some other sources ($B = 0.503$, $p < 0.1$) could significantly predict the overall air quality satisfaction levels. When housing condition variables were added to the regression Model 2, the odour problems from the external sources ($B = 0.866$, $p < 0.1$) still significantly predicted the overall air quality satisfaction levels, including the duration of the residence ($B = 0.067$, $p < 0.05$). After including the socio-economic and demographic factors in Model 3, the predicting role of odour problems from the external sources ($B = 1.057$, $p < 0.05$), the duration of the residence ($B = 0.051$, $p < 0.1$), alcohol consumption ($B = 0.484$, $p < 0.01$) and smoking habit ($B = -0.251$, $p < 0.01$) had a statistically significant effect on overall air quality satisfaction.

4. Discussion

The statistical analyses from this study identified the range of factors that can impact the perceived thermal comfort and air quality of the social housing residents. Model 3, which incorporated the most comprehensive selection of parameters in the study, indicated that in terms of overall environmental satisfaction, air quality satisfaction, age, smoking habit, employment status and educational level statistically significantly predicted respondents' physical health. For the same Model 3, mental health was significantly correlated with air quality satisfaction, thermal environment satisfaction and alcohol consumption status. Looking at individual variables and their impact on perceived air quality, Model 3 showed statistically significant relationships with odours from external sources, duration of residence in the housing, alcohol consumption and smoking habit.

Findings from other studies corroborate some of the results of this work. Vakalis et al. [45] examined indoor environmental quality in Canadian social housing and found that poor air quality was experienced by 80% of residents on a weekly basis. Cooking, smoking and outdoor odours contributed to this perceived poor air quality. The study by Langer et al. [46] indicated the importance of perceived air quality studies as they found that residents' perceptions of their indoor air quality were more positive than would be indicated by objective measurements. Additionally, as with this current study, Langer found that perceived indoor air quality was strongly linked to an occupant's social status. Alapieti et al. [47] studied people's perceptions of air quality for a range of ventilation rates and volatile organic compounds (VOCs). Surprisingly, they found that perceived air quality could be high even when VOC levels were high, suggesting that VOCs are not a defining feature of perceived air quality. This type of finding indicates the importance of the suggestion by Pei et al. [48] that an occupant's perception of air quality should be incorporated into any traditional physical air quality monitoring programme. The findings from the current study would support this suggestion.

The correlation between mental health outcomes and variables such as air quality satisfaction, thermal environment satisfaction, and alcohol consumption status shows the complex relationship between environmental factors and psychological well-being. Emerging evidence suggests that exposure to air pollution, both indoors and outdoors, may precipitate neurocognitive disorders and adversely affect mental health through mechanisms such as neuroinflammation, oxidative stress, and cerebrovascular damage [49–52]. These pathophysiological changes are linked to the onset of depression via neurotransmitter and hormonal dysregulation [53], with long-term exposure to particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) significantly elevating the risk of depression [54].

Additionally, dissatisfaction with the indoor temperature has been identified as a determinant of mental health scores among low-income residents [55], with extreme temperatures being associated with a spectrum of mental health issues, from increased suicide risk to worsened self-reported well-being [56,57].

The complex relationship between environmental factors and psychological well-being is further complicated by the role of alcohol consumption. This study found that frequent alcohol consumption ($\geq$4 times per week) significantly negatively predicts the self-rated mental health component but not the physical health of social housing residents. According to previous studies, those with an increasing drinking trajectory had an increased risk of experiencing physical and mental health morbidity and mortality as well as an economic disadvantage [58,59]. A recent systematic review of the role of alcohol use in socio-economic inequalities concluded that people with heavy episodic alcohol use explained a significant share of socio-economic inequalities in mortality of 27% compared to the high socio-economic status individuals [60]. Individuals experiencing environmental discomfort or dissatisfaction may resort to alcohol as a coping mechanism, potentially leading to a cycle where alcohol use exacerbates mental health issues, thereby reinforcing the negative impact of suboptimal living conditions on psychological well-being [61–63]. These findings highlight the critical need for comprehensive environmental health strategies that address air quality and thermal comfort to mitigate their potential impacts on mental health.

A review of indoor air quality indexes by Pourkiaei and Romain [64] indicated that objective measurements rather than subjective surveys had become more prevalent in air quality research. Future work should try to readdress this balance, given the importance of non-objective environmental and behavioural components on a person's perception of their air quality and their physical and mental health.

5. Conclusions

This study investigated the complex relationships between indoor environmental quality (IEQ), lifestyle behaviours, and health outcomes among residents of social housing in the Zerdely micro-district. The findings show that satisfaction with air quality and thermal comfort, alongside factors such as age, smoking habits, employment status, educational level, and alcohol consumption, significantly influence both physical and mental health. These results highlight the complex interaction between the built environment and resident well-being, emphasising the importance of considering both objective and subjective assessments of IEQ in research.

This study emphasises the need to design and maintain social housing that not only meets physical standards of air quality and thermal comfort but also addresses the perceptions and behaviours of residents. Integrating objective measures of environmental quality with residents' subjective experiences will provide a more comprehensive understanding of how IEQ impacts health and well-being.

In conclusion, by emphasising the importance of IEQ in the health outcomes of social housing tenants, this study contributes to the ongoing discussion around public health, urban planning, and social policy. It calls for a multidisciplinary approach to housing design that prioritises the health and satisfaction of residents in social housing settings, resulting in more equal and healthy urban communities.

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