THE EFFECT OF OCCUPANTS' LIFESTYLE ON THE INDOOR AIR QUALITY IN RESIDENTIAL UNITS: A CASE STUDY OF ARAB RESIDENTS IN ANKARA

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Title of the Thesis : **The Effect of Occupants' Lifestyle on the Indoor Air Quality of the residential units: A Case Study of Arab Residents in Ankara**

Submitted by **Ehab Ali Eshtiwi**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University

Prof. Dr. Can ÇOĞUN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asst. Prof. Dr. İpek MEMİKOĞLU
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU
Supervisor

Examination Date : 07.02.2018

Examining Committee Members

Prof. Dr. Füsun Demirel (GAZİ UNIVERSITY)

Asst. Prof. Dr. Özge SÜZER (ÇANKAYA UNIVERSITY)

Asst. Prof. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU (ÇANKAYA UNIVERSITY)

ORIGINALITY STATEMENT

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Ehab Ali ESHTIWI

Signature

Date : 07.02.2018

ABSTRACT

THE EFFECT OF OCCUPANTS' LIFESTYLE ON THE INDOOR AIR QUALITY IN RESIDENTIAL UNITS: A CASE STUDY OF ARAB RESIDENTS IN ANKARA

ESHTIWI, Ehab Ali
M.S., Department of Interior Architecture, Çankaya University

Supervisor: Asst. Prof. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU

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Indoor air quality (IAQ) is considered as one of the most important aspects in the design of interior spaces regarding residential units, especially for the reason that people spend the majority of their time in these spaces. Therefore, the indoor environment and air quality have direct and indirect impacts on the health of the occupants. This study aims to investigate the impact of interior design criteria and occupants' lifestyle on the indoor air quality, and the preference and satisfaction from IAQ, within residential units in Çankaya, Ankara, Turkey. Objective measurements (total VOC, CO and CO_2) are recorded in the living room space through visits to the houses of 20 people using measuring devices (MultiRAE Lite for TVOC and ToxiRAE Pro PID for CO and CO_2), while the researcher performed an investigation on architectural design aspects, including cross-ventilation and finishing materials. Information of the lifestyle habits (cooking, cleaning and smoking) are collected through a questionnaire methodology. The results show that cross-ventilation is correlated to less total VOC readings, as well as less sickness frequency and allergies within the members of the household. Moreover, using open windows as a ventilation method in the kitchen and using non-chemical cleaning agents are found to be correlated to less pollutants' concentration in the indoor environment.

Keywords: indoor air quality, cross-ventilation, indoor pollutants, household lifestyle

ÖZ

EV SAKİNLERİNİN YAŞAM BİÇİMİNİN İÇ MEKAN HAVA KALİTESİNE OLAN ETKİSİ: ANKARA'DA YAŞAYAN ARAPLAR ÜZERİNE BİR ÇALIŞMA

ESHTIWI, Ehab Ali
Yüksek Lisans, İç Mimarlık Anabilim Dalı, Çankaya Üniversitesi
Tez Yöneticisi: Yrd. Doç. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU

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İç mekân hava kalitesi, yerleşim birimlerinin iç mimari tasarımında, özellikle de kişilerin zamanlarının çoğunu geçirdiği için en önemli unsurlardan biri olarak düşünülmektedir. Dolayısıyla, iç mekan hava kalitesinin, mekan kullanıcılarına doğrudan ve dolaylı etkileri bulunmaktadır. Bu çalışma, iç mekan tasarımı kriterlerinin ve Ankara, Çankaya'daki yerleşim birimlerinde yaşayan Arap asıllı ev sakinlerinin yaşam biçimlerinin iç mekan hava kalitesine olan etkisini ve kullanıcıların tercih ve memnuniyetlerini araştırmayı amaçlamıştır. Nesnel ölçümler (toplam VOC, CO ve CO_2), MultiRAE Lite ve ToxiRAE Pro PID kullanılarak 20 farklı ailenin evlerine yapılan ziyaretler yoluyla yapılmıştır. Ayrıca, ziyaret edilen evlerde çapraz havalandırma ve bitirme malzemeleri de dahil olmak üzere mimari tasarım konularında da gözlemler gerçekleştirilmiştir. Yaşam tarzı alışkanlıklarının (pişirme, temizlik ve sigara içilmesi) bilgileri anket yoluyla toplanmıştır. Sonuçlar, çapraz havalandırmanın, daha az toplam VOC ölçümleri ile ilişkilendirilmesinin yanı sıra, ev sakinlerinin daha az hastalanma ve alerjik rahatsızlık geçirmeleri ile de ilişkilendirilmiştir. Ayrıca, doğal havalandırma yönteminin kullanılması ve ağır kimyasal içeriği olmayan temizlik maddelerinin kullanılması, düşük kirletici konsantrasyonuyla ilişkilendirilmiştir.

Anahtar kelimeler: iç mekân hava kalitesi, çapraz-havalandırma, iç mekan hava kirleticileri, yaşam tarzı

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ABBREVIATIONS AND SYMBOLS

ASHRAE	The American Society of Heating, Refrigerating, Air-Conditioning Engineers
CFD	Computational Fluid Dynamics
CO	Carbone Monoxide
CO_2	Carbone Dioxide
COPD	Chronic Obstructive Pulmonary Disease
H_2S	Hydrogen Sulfide
HCHO	Formaldehyde
IAQ	Indoor Air Quality
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NO_2	Nitrogen Dioxide
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
SBS	Sick Building Syndrome
SO_2	Sulfur Dioxide
TCE	Trichloroethylene

TVOC	Total Volatile Organic Compounds
VOC	Volatile Organic Compound

1. INTRODUCTION

1.1 Indoor Air Quality (IAQ) and Lifestyle

As people spend most of their indoor time inside houses, the air that they breath in these environments plays a major role in determining their health status on the short-term and long term. Therefore, the ındoor air quality (IAQ) is an important parameter to monitor to ensure a healthy indoor environment for the house residents (Pickett & Bell, 2011). Nonetheless, when researching indoor air quality, the specialists often monitor the existence of pollutants in the house environment such as carbon monoxide, Formaldehyde, Naphthalene, and many other chemicals that could form risks on human health. In solving these issues, the Architects and Engineers follow certain design codes that assist them to produce an overall design that empowers a healthier indoor air quality for the dwellers (WHO Europe, 2010).

Furthermore, there are many factors that cause the indoor air quality to reduce or for the pollutants to accumulate in the indoor environment. However, most of the pollutants in the house environment is a result of the lifestyle of the house residents. For instance, using cleaning material, cooking, and smoking can change the daily concentrations of the pollutants in the air, especially is ventilation mechanisms are not installed within the concerned space (CDC, 2016). While the indoor air quality (IAQ) is always studied from the perspective of the design of the buildings, the occupants in the space has a contribution to the subject. The habits and daily activities adopted by the occupants can also influence the IAQ positively or negatively.

In this study, the indoor air quality is investigated in the houses in Çankaya, Ankara occupied by Arabic people, which is performed through studying the lifestyle of the Arabic residents in Ankara and an architectural examination for the house layouts and ventilation mechanisms.

1.2 Aim and Scope

This thesis aims to study the extent of the occupants' lifestyles on the IAQ and the ideal measures that should be taken to increase the quality of the indoor environment by the occupants. This is based on whether the design of the unit supports good or bad IAQ, the occupants could change a sick building to a healthy one by adopting a different lifestyle. Moreover, the scope of this research includes studying IAQ perception and satisfaction levels of the Arabic people from different countries, who are residing in Ankara, Turkey. The study will be performed through studying the following factors:

1. The lifestyle parameters of the residents including:
    a. Cleaning habits of the occupants and the used cleaning material
    b. Cooking practices that are used (type of food, kitchen ventilation, etc.)
    c. Indoor and adjacent plantation in the residential unit
    d. Other factors (smoking, daily activities, daily house ventilation, etc.)
2. House design and architectural factors including:
    a. Cross ventilation
    b. Finishing materials
3. Performing indoor air quality measurements for pollutants: Total VOC, CO and CO_2.

The methodology of the study is performed through two main tools, which are:

1. Pollutants' measurements in different areas of the house using electronic devices.
2. Questionnaire application to one household member, who can state the daily and periodic habits of the residents to understand its effects on the IAQ, and a self-evaluation of the IAQ perception and satisfaction level.

Furthermore, the main target for the research is to establish a set of healthy lifestyle guidelines for the residential space users to achieve the desired air quality.

1.3 Research Questions

The research will seek answers through studying the literature and previous studies and researches that examined the air quality of indoor spaces, especially the ones directly related to houses and residential units. Moreover, the methodology adopted in this study allows the researcher to assess the IAQ in the Arabic houses in Ankara and establish the relation between the occupants' lifestyle and the air quality in their houses.

To achieve the purpose of this thesis the main question of the research is:

Q1. How does the lifestyle of the Arabic residents' in Ankara affect the indoor air quality in their houses?

> Q1.1. How does lifestyle habits, including cleaning, cooking, indoor plantation and smoking correlate the indoor air quality?

Q2. What are the effects of cross ventilation and finishing materials on IAQ?

> Q2.1. How does the cross-ventilation implementation affect the indoor air quality?
>
> Q2.2. What is the impact of using different finishing materials on the indoor air quality?

Q3. Why adopting certain lifestyle changes and design criteria could change the health impacts of IAQ on the residential space occupants?

> Q3.1. What are the pollutants that affect the indoor air quality and the health of the house residents?
>
> Q3.2. What are the causes of high levels of pollutants in the indoor environment?
>
> Q3.3. What is the satisfaction level from the indoor air quality of the Arab residents in Ankara?

1.4 Thesis Structure

This research contains five main chapters, starting by the present introduction chapter which establishes the study's significance, main aim, scope, and research questions. The second chapter surveys the literature on the parameters affecting the IAQ and the impact of the residents' lifestyles on IAQ. Moreover, previous studies are reviewed for results comparison and methodology formation. The research methodology and the specification of the hypotheses are included in the third chapter. The parameters used in the research, questionnaire design and information about the sample and analysis techniques are also provided.

The fourth chapter narrates the findings of the IAQ readings and questionnaire findings, which are analyzed and discussed. The final chapter draws the conclusions of the research by answering the design questions and testing the hypotheses. Moreover, a set of recommendations for residential space users concerning their lifestyle and house selection are provided. Moreover, future research areas are identified for further exploration.

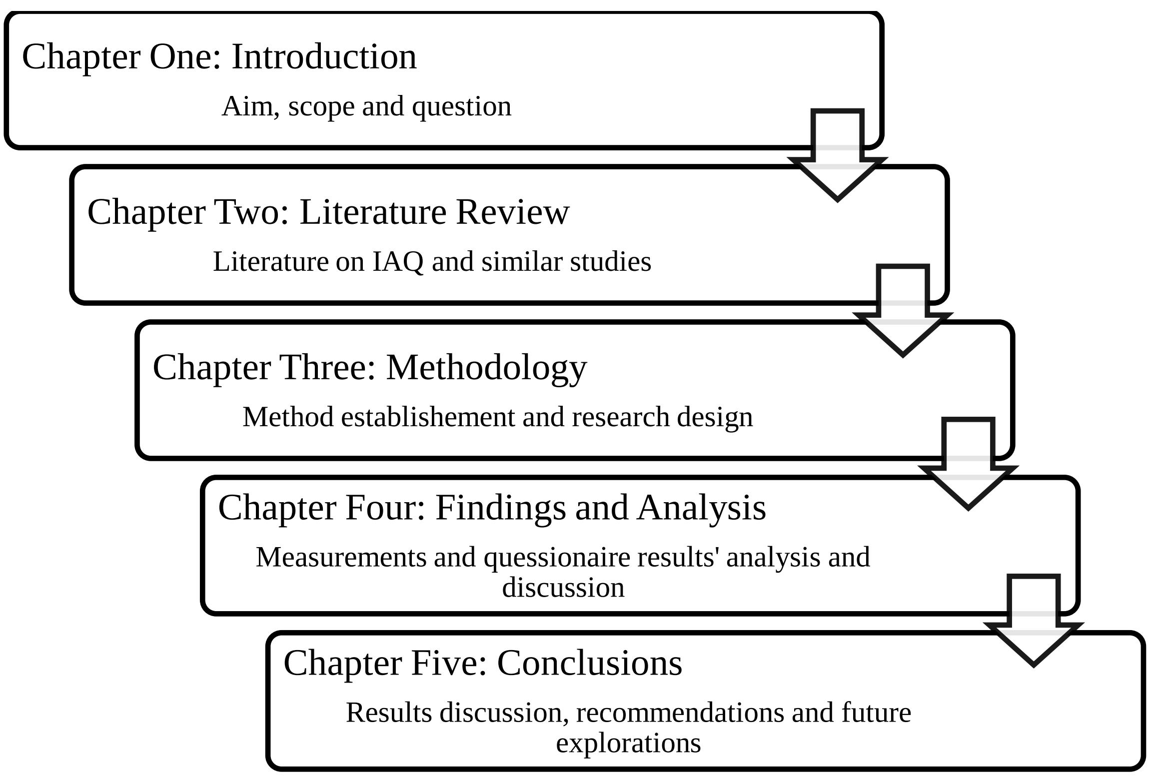

Figure 1: Thesis structure scheme

2. LITERATURE REVIEW

It is important to study the literature in order to understand the way indoor air quality is researched and structured. Therefore, several studies are reviewed in this research to facilitate the following:

1. The choice of IAQ pollutants that are chosen for the study.
2. The methodologies used for measurement, including subjective and objective methods.
3. Narration of the literature findings and conclusion, which would enable discussing the results of the research.

Table 2.1 provides a list of some of the significant research on the subject, along with their studied parameters, methodologies, findings and conclusions. The majority of the studies have chosen certain pollutants, architectural properties and measured the satisfaction of the users from the IAQ, through subjective and objective measurement tools.

Table 2.1: Main literature matrix

Author and Date	**Studied Parameters**	**Methodology**	**Findings & Conclusions**
(Pickett & Bell, 2011)	TVOC, $PM_{0.5}$, CO_2 & CO Houses & nurseries with infants	Measurement by device & Survey	High concentrations of pollutants in houses and nurseries imposing health risks on infants
(Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007)	Natural ventilation setting outs	Surveyed residential units and applying CFD model	Cross ventilation is the most effective natural ventilation technique, combined with openings that are not less than 20% of the floor area
(Barnes, Mathee, Thomas, & Bruce, 2009)	House fuel sources and IAQ	Statistics analysis	Reduction in using biomass and fossil fuels in South Africa contributed into enhancing IAQ in houses

Table 2.1: Main literature matrix (Continued)

Author and Date	Author and Date	Author and Date	Author and Date
(Kamaruzzaman & Sabrani, 2011)	IAQ user satisfaction and impact on performance	User survey	Poor IAQ increase stress and affect occupants' performance
(Mantanis, Vouli, Gonitsioti, & Ntalos, 2007)	Formaldehyde levels in new apartments	Measurements by device	High levels of formaldehyde were found in new apartments that are decreasing by regular natural ventilation
(Grimley, Evans, Mulcahy, McFarlane, & Gilmore, 2010)	$PM_{2.5}$ and Air Nicotine	Measurements by device and users' survey	Smoking ban legislation lowered levels of $PM_{2.5}$ and nicotine in bars in Northern Ireland, and increased users' satisfaction of IAQ
(Funk, et al., 2014)	CO, HCHO, H_2S, NO_2 and SO_2, Ultrafine PM, $PM_{2.5}$, PM_c and PM_{10}	Measurements by device and user's survey	High levels of pollutants are linked to the cooking and central air conditioning
(Wolverton, Johnson, & Bounds, 1989)	Absorption of plants to benzene, TCE and formaldehyde	Measurement by device in controlled settings	Different species of plants have different absorption capabilities to the tested pollutants, which were mostly considered significant

2.1 Indoor Air Quality, Pollutants and Sick Building Syndrome

There are several factors that affect the indoor environmental quality (IEQ), which are:

1. Thermal comfort
2. Indoor air quality
3. Acoustic quality
4. Lighting quality.

Nonetheless, many studies and reports have demonstrated that the indoor air quality (IAQ) is the major contributor among all factors in determining the occupants' health in any type of space (Yee, 2014) (Sulaiman, Wan Yusoff, Pawi, & Wan Kamarudin, 2013). The IAQ can affect the general health of the occupants, which a low quality would cause what is known as the *sick building syndrome* (SBS) affecting 30% of indoor users according to World Health Organization (Kamaruzzaman & Sabrani, 2011). Table 2.2 shows some of the symptoms that may arise due to the Sick Building Syndrome.

Table 2.2: Symptoms caused by *sick building syndrome* (Kamaruzzaman & Sabrani, 2011)

Organ	Symptom	Impact
Eye	Irritation Dryness Watering	Tiredness, itching, redness, burning effect, and hardness using optical aids
Nose	Irritation Running Blockage	Nose bleeding, itchiness and sneezing
Throat	Dryness Soreness	Pharyngeal symptoms and swallowing difficulty
Skin	Dryness Itching Irritation	Rash, erythema, rosacea, urticaria, xerodermia
Other	Headache Lethargy Lack of concentration	

Moreover, there are proven impacts of indoor air quality on the respiratory and cardiovascular system, which can be affected by the following health issues:

1. Chronic obstructive pulmonary disease (COPD): a disease that obstruct the air from flowing to the lungs, which can be caused by direct smoking, second hand smoking and combustions.
2. Asthma: many pollutants such as nitrogen oxides, airborne allergies and endotoxin resulting from poor indoor air quality can cause this issue.
3. Acute Respiratory Infection (ARI): mainly has fatal impact on children due to exposure to biomass fuels and fossil fuels combustion. Moreover, the ventilation

of the indoor environment plays a major role in severing or alleviating the impacts of the combustion activities leading to ARI.

4. Lung Cancer: The World Health Organization published statistics that more than 15% of the lung cancer deaths are caused by pollution in the house environment (Tsaloglidou, Koukourikos, Pantelidou, & Kourkouta, 2015).

Other than contributing to occupants' physical health, the indoor air quality has a significant impact on the performance and comfort of occupants in the indoor environment. In a study performed on staff in an office building setting, a study found that different buildings had different ventilation, comfort and stress rates, which affected the performance of the employees (Kamaruzzaman & Sabrani, 2011).

Indoor air quality is also affected by Volatile Organic Compounds (VOC's), which are carbon-based chemicals that are considered one of the most dangerous indoor air pollutants (Tsaloglidou, Koukourikos, Pantelidou, & Kourkouta, 2015). Nevertheless, there are many pollutants that were classified as dangerous to the human health by the World Health Organization, which is shown along with common sources and health effects in Table 2.3.

Table 2.3: Indoor air pollutants, their sources and effects (WHO Europe, 2010)

Pollutant	Indoor Source	Health Issues
Benzene	Building Material Furniture Attached garages Heating and cooling systems Stored Solvents Smoking	Fatality Fatigue Headaches Blood and Bone marrow defects Mato-toxicity

Table 2.3: Indoor air pollutants, their sources and effects (WHO Europe, 2010) – (Continued)

Pollutant	Indoor Source	Health Issues
Carbon monoxide	Combustion (cooking/ heating) Outdoor air Smoking	Immediate symptoms such as headaches, nausea, dizziness, etc. Breathing difficulties Poisoning Fatality Brain functions Memory defects Low birth weight Heart failure Stroke Asthma
Formaldehyde	Combustion Building material Cleaning products Furniture Wood products Consumer products	Irritation (Eye, nose, skin) Nasopharyngeal cancer
Naphthalene	Paints Building material Gardening material Leather Toilet deodorizer	Hemolytic anemia Poisoning Colon Cancer
Nitrogen dioxide	Combustion Smoking	Eczema Ear, nose and throat infections Breathing issues
Polycyclic aromatic hydrocarbons (PAH)	Combustion Smoking Outdoor sources Cooking fat content	Anti-DNA adduction Lung cancer Bladder cancer Breast cancer Immune system defects Low birth weight Asthma Heart disease Neuro system defects

Table 2.3: Indoor air pollutants, their sources and effects (WHO Europe, 2010) – (Continued)		
Pollutant	**Indoor Source**	**Health Issues**
Radon	Soil and rocks Building material	Lung cancer Leukemia
Trichloroethylene (TCE)	Cleaning material Building material	Depression Kidney defects Skin irritation Liver cancer Neurological damage Cervical cancer Immune system defects Adverse pregnancy impacts

2.2 Indoor Air Quality in Residential Context

Houses are unique in their environment since people spend most of their time in them. Therefore, there are several factors within the residential unit that affects their indoor air quality. Several researches in the literature studied IAQ from generic and specific points, adopting different methodologies. In a study that involved 628 households in the United Arab Emirates, a hybrid methodology of measurement and survey was used in order to measure pollutants and correlate them to questionnaire answers based on the daily activities within each household and around it (Funk, et al., 2014).

In the pollutants measurement part, Funk, et al. (2014) divided the indoor pollutants into two measure categories, which are:

1. Gaseous Pollutants: CO, HCHO, H_2S, NO_2 and SO_2
2. Particulate Matter: Ultrafine PM, $PM_{2.5}$, PM_c, PM_{10}, and mineral elements.

Moreover, the study added a questionnaire for selected household occupants in order to understand the relation between the daily factors and the pollutants' measurements. Table 2.4, adopted from the study, correlates the measurements' readings to the questionnaire answers. The most significant readings are chosen according to the parameters that influenced the IAQ from the referenced study (Funk, et al., 2014).

Table 2.4: Prediction of CO, $PM_{2.5}$ and PM_{10} from questionnaire answers (Funk, et al., 2014)

Questionnaire Parameters	**CO (ppm)**			**$PM_{2.5}$ (μg/m³)**			**PM_{10} (μg/m³)**		
	No	**Yes**	***P***	**No**	**Yes**	***P***	**No**	**Yes**	***P***
Vehicles park within 5 meters from the house	0.954 (218)	0.919 (362)	0.803	7.21 (206)	7.48 (329)	0.030	45.6 (206)	46.1 (329)	0.038
Split unit air conditioning	0.900 (504)	1.145 (72)	0.001	7.22 (464)	8.41 (67)	0.032	45.5 (464)	48.0 (67)	0.105
Central air conditioning	0.928 (461)	0.936 (115)	0.631	8.12 (423)	4.38 (108)	1.000	50.9 (423)	24.3 (108)	1.000
Kitchen attached to living room	0.879 (363)	1.056 (156)	0.005	8.11 (327)	6.24 (149)	1.000	51.4 (327)	38.4 (149)	1.000
Windows opened daily	0.969 (196)	0.914 (382)	0.884	7.38 (181)	7.43 (353)	0.189	46.6 (181)	45.8 (353)	0.353
Construction sites within 100 meters	0.907 (314)	0.965 (260)	0.188	7.51 (282)	7.28 (248)	0.659	45.8 (282)	46.0 (248)	0.451
Smoking inside house	0.881 (353)	1.066 (117)	0.005	7.42 (322)	7.73 (110)	0.338	44.8 (322)	50.9 (110)	0.101
Incense used more than once per week	0.960 (36)	0.928 (483)	0.759	8.80 (34)	7.44 (442)	0.683	49.1 (34)	47.3 (442)	0.233
Usage of electrical heater	0.929 (541)	0.972 (34)	0.457	7.39 (496)	6.76 (34)	0.550	45.3 (496)	49.2 (34)	0.058

Numbers between ( ) represents the number of households and the number above represents the average substance reading. *P* is the correlation factor to the closest 0.05

The correlations in the study show a strong relationship between central air conditioning, attachment of kitchen to the living room, and particles in the indoor air. The test performed in the study is a one-sided t-test to correlate the concentrations and the presence of the answers from the questionnaire (Funk, et al., 2014).

Furthermore, in another study performed on South African households, the relation between the type of fuel used and the concentration of air pollutants is studied. The results of the study show that the reduction in using fossil fuels in heating and cooking from 1996 to 2007, as shown in Table 2.5 below, was associated with a median reduction in indoor air pollutants of 50% (Maximum PM_{10} 96% and CO 95%) (Barnes, Mathee, Thomas, & Bruce, 2009).

Table 2.5: Increase in using electricity as a fuel in South Africa (Barnes, Mathee, Thomas, & Bruce, 2009)

Year	**1996**		**2001**		**2007**	
Fuel*	**Cooking**	**Heating**	**Cooking**	**Heating**	**Cooking**	**Heating**
Electricity	47%	45%	51%	49%	67%	59%
Gas	3%	1%	3%	1%	2%	1%
Paraffin	21%	14%	21%	15%	15%	13%
Wood	23%	27%	21%	25%	15%	20%
Coal	4%	8%	3%	7%	1%	4%
Animal dung	1%	<1%	1%	<1%	<1%	<1%

* There are negligible fuel sources

The last study in this section examines the presence of Formaldehyde in 30 new built residential units in the city of Karditsa, Greece with new installed furniture and casework. Three measurements were made, the first two in the first visit after construction and the third measurement was made after six months from the first two measurements (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007). As seen in Table 2.3, Formaldehyde has several sources, especially in a new constructed or renovated house. The compound is applied during to the manufacturing of furniture, casework, paint and fabrics. However, it has some adverse health impacts on the space occupants, which could lead to cancerous effects (WHO Europe, 2010). The method of the study was simply demonstrated through direct measurement in the living room, bedroom, kitchen casework and bedroom casework. The measurements were carried out using a special formaldehyde meter. Since formaldehyde concentrations can vary depending on the temperature, the authors had to take temperature measurements at each reading.

The procedure was performed on two phases (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007):

1. First set of readings: First reading performed early in the morning prior any ventilation and the second one performed after 30 minutes of ventilation. Since

kitchen and toilet caseworks are closed furniture, the second reading after ventilation was not made, as it is not a common practice to ventilate casework.

2. Second set of readings: performed after 6 months from the first set of reading, as the occupants were asked to keep ventilating their apartments on a daily basis. The readings at this set were performed in the same way as the first set.

Tables 2.6 below shows the readings in the thirty houses at the first set of readings. It is significant to note that formaldehyde has a European safety limit of 0.1 ppm. Tables 2.7 below shows the readings in the thirty houses at the second set of readings (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007).

Table 2.6: First set of readings of Formaldehyde (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007) – Numbers are the count of houses within the specified limits

Space	<1 ppm	1 – 3 ppm	3 -5 ppm	>5 ppm
Prior Ventilation at 27.8º C				
Living room	19	10	1	0
Bedroom	20	10	0	0
Kitchen casework	8	7	7	8
Bedroom casework	1	3	6	20
Post 30 mins Ventilation at 25.5º C				
Living room	24	6	0	0
Bedroom	26	4	0	0

Table 2.7: Second set of readings of Formaldehyde (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007) – Numbers are the count of houses within the specified limits

Space	<1 ppm	1 – 3 ppm	3 -5 ppm	>5 ppm
Prior Ventilation at 18.7º C				
Living room	28	2	0	0
Bedroom	29	1	0	0
Kitchen casework	28	2	0	0
Bedroom casework	26	4	0	0
Post 30 mins Ventilation at 16.5º C				
Living room	30	0	0	0
Bedroom	30	0	0	0

The above study results show that regular ventilation of the house, especially at new houses where many new installed material and furniture that contain pollutants are present, can reduce the pollutants concentrations in the indoor environment significantly instantly and on the long run. Moreover, the study recommends that the consumers and developers to purchase wood products and furniture with high safety standards for pollutants contents and emissions, adopt a habit of daily natural ventilation especially in new apartments and in hot temperatures, which increases the emission of some pollutants, and avoid smoking in new apartments (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007).

2.3 Indoor Air Quality and Occupants' Lifestyle

Adopting certain lifestyles and daily techniques can impact the pollutants' content in the indoor air in a significant manner. Therefore, this study considers this element an essential one to study beside the different design factors that are also incorporated in the research. This section will review the literature for studies and information that could help the researcher establishes the necessary knowledge about the impact of the lifestyle on the indoor air quality in order to be able to perform the case study in a knowledgeable manner and be able to compare results with the results of previous studies.

2.3.1 Cleaning

The activity of cleaning the house cannot be eliminated from a household. However, the type of materials and agents that are used in cleaning and sanitizing activities, and the way these materials are stored can affect the amount of VOC's emitted into the indoor environment, which affects the indoor air quality (Buekens & Schroyens, 2003).

Most of the chemical-based cleaning, sanitizing and scented products contain high levels of VOC's, which affects the human health on the short and long runs. If a cleaning process lasts for two hours in any space, the VOC can raise from less than 40 $\mu g/m^3$ to more than 20,000 $\mu g/m^3$, which raise the risk for health impacts to a high level (Green Guard, 2007). Table 2.8 below shows different VOC's and the type of products they usually form.

Table 2.8: VOC's and associated products (Green Guard, 2007)

VOC's	Type of Product
1, 4 dioxane	Stain remover
Acetaldehyde	Scents, perfume and disinfectants
Acetic acid esters	Surface cleaners
Acetone	Surface cleaners and nail polish removers
Butoxyethanol	Surface cleaners
Butyl acetate	Surface cleaners and scents
C6 – C10 substituted alkanes	All cleaners, polishers and waxes
Dichlorobenzene	Deodorizers
Dipropylene glycol	Surface cleaners
Ethanol	Disinfectants
Formaldehyde	Biocides
Isobutane and Isobutene	Aerosol cleaners
Isopropanol	Disinfectants
Limonene	Orange scent
Methoxyethanol	Surface cleaners
Methoxyethoxyl ethanol	Surface cleaners
Methyl methacrylate	Hard surface cleaners
Naphthalene	Disinfectants and moth repellants
Phenol	Disinfectants
Pinene	Pine scent
Propylene glycol	Surface and aerosol cleaners
Siloxanes	Waxes and polishes
Tetrachloroethylene	Dry Cleaners
Trichloroethylene	Degreasers and stain removers

2.3.2 Cooking and Indoor Combustion

When looking of the impacts of the cooking activities on the indoor air quality, the focus is mainly drawn to the combustion events that occur during the heat production. Thus, the fuel that is used in producing the heat plays a major role in determining the indoor air quality in a house. Studies show that populations that depend on biomass fuels in cooking, mainly in developing counties, have demonstrated high levels of indoor air pollutants, which was directly linked to the high percentage of heart diseases and low blood pressure. A review shows that residential spaces that suffer from this issue have a concentration of pollutants ($PM_{2.5}$) that range between 52 μg/m^3 to 105 μg/m^3 depending on the season and the used combustion assembly (Simkhovich, 2013).

Furthermore, as the statistics in Turkey show that the main fuels used in combustion at houses are coal and natural gas, both types of fuels have many associated pollutants and subsequently health risks. A World Health Organization's report indicated that using this type of fuel in cooking and heating produces many air pollutants in the house environment including nitrogen oxides and carbon monoxide. The report recommends using proper assemblies when using this type of fuel, including proper ventilation (WHO, 2014). The reviewed studies indicate that the cooking and indoor combustion activities play a major role into determining the indoor air quality, taking into consideration the type of fuel used and the ventilation technique used to minimize its effects.

2.3.3 Plantation

Utilizing plants to generate increased oxygen in outdoor and indoor environments is not a new usage. However, it is scientifically proven that plantations absorb toxins from air and soil, which helps to significantly decrease their concentrations and lead to a healthier indoor air quality (Mercola, 2016). In a case study by the National Aeronautics and Space Administration (NASA), several plant types were tested in absorbing pollutants from indoor environments using a special assembly of activated carbon and ventilation mechanism under the plant pots as shown in Figure 2.1 below (Wolverton, Johnson, & Bounds, 1989).

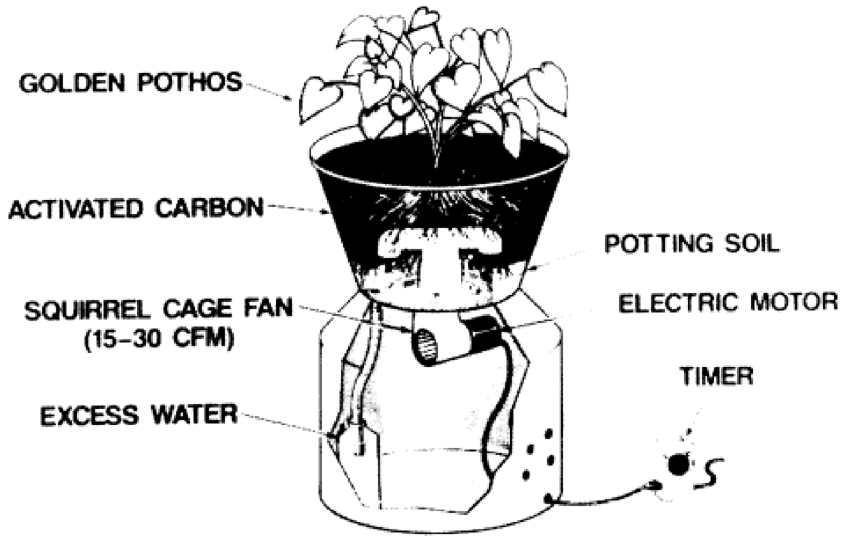

Figure 2.1: Plantation purification assembly using activated carbon and ventilation fan (Wolverton, Johnson, & Bounds, 1989)

The study was performed on different plantation species, which have high green surface area, and were exposed to controlled and sealed room environments containing Trichloroethylene, Benzene and Formaldehyde for 24 hours. Table 2.9 shows the absorption results of five different plants' species at 30º C ± 1. The leak control reading shows errors that may occur in readings due to leakages from the room.

Table 2.9: Pollutants removed by plantation assembly (Wolverton, Johnson, & Bounds, 1989)

Species Common Name	Formaldehyde			Benzene			Trichloroethylene		
	Initial ppm	Final ppm	% Removed	Initial ppm	Final ppm	% Removed	Initial ppm	Final ppm	% Removed
Mass Cane	20	6	70	14	11	21.4	16	14	12.5
Pot Mum	18	7	61	58	27	53	17	10	41.2
Gerber daisy	16	8	50	65	21	67.7	20	13	35
Warnechei	8	4	50	27	13	52	20	18	10
Ficus	19	10	47.4	20	14	30	19	17	10.5
Leak Test	18	17.5	2.8	20	19	5	20	18	10

Other plantation types were tested against the same pollutants and yielded different results. Nonetheless, this illustrates the effectiveness of plantation in removing pollutants from the indoor environment at different rates. One of the effective species in absorbing pollutants in the experiment was the golden pothos, combined with the activated carbon, which was able to bring high concentrations of benzene and trichloroethylene to the zero point within two hours. Figure 2.2 shows a graph of the readings for the golden pothos in 8 inch activated carbon filter (Wolverton, Johnson, & Bounds, 1989).

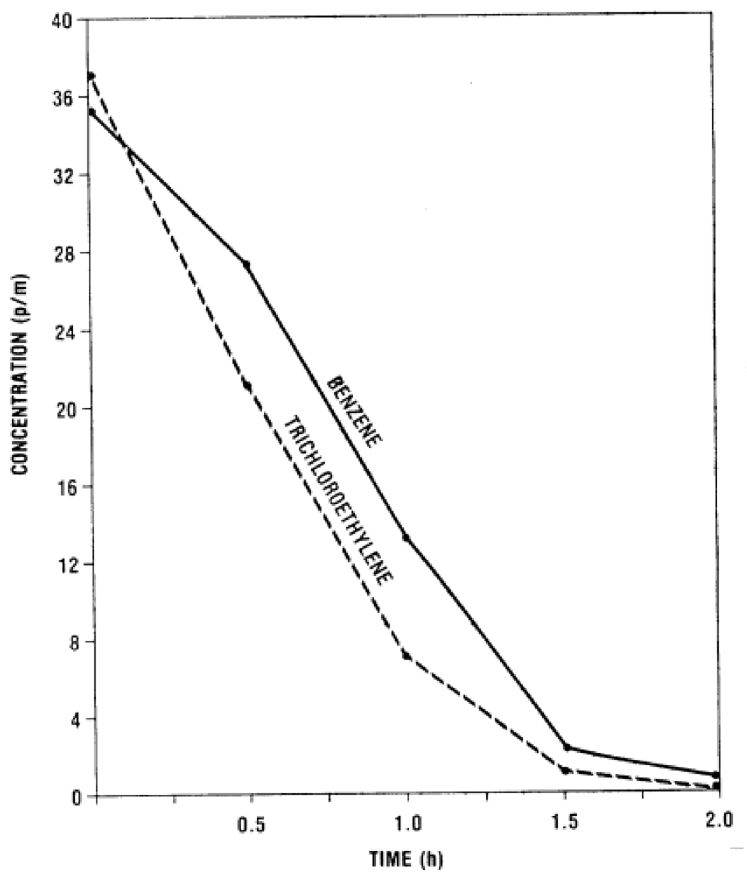

Figure 2.2: Absorption of Golden Pothos for benzene and trichloroethylene at high concentrations (Wolverton, Johnson, & Bounds, 1989)

2.3.4 Smoking

There are many studies that have proven that smoking in any space increases the indoor air pollution significantly. A review, that was performed on the indoor air quality and the different factors that affects it, revealed that a study measured the air pollutants ($PM_{2.5}$) inside a gambling facility and in its outside environment, and the concentration were 53.8 $\mu g/m^3$ and 4.3 $\mu g/m^3$, respectively (Simkhovich, 2013). This shows a massive increase by 1251% in air pollutants resulting from smoking in indoor environments. Another study performed in the Northern Ireland, UK studied the concentration of Nicotine and other air pollutants in bars before and after a passed legislation that prohibited smoking indoors. The study found that the concentrations of air pollutants disappeared completely within the next 12 months after the legislation, while the air pollutants decreased by an average of 22.4% depending on the city included in the study (Grimley, Evans, Mulcahy, McFarlane, & Gilmore, 2010).

Furthermore, other studies elaborated on the many health impacts of the combustion activities, such as smoking, in the indoor environment. Table 2.10 below shows a list of the main air pollutants that results from smoking and their impact on the occupants' health status (Slezakova, Morais, & do Camra Pereira, 2012).

Table 2.10: Health impacts from smoking in indoor spaces (Slezakova, Morais, & do Camra Pereira, 2012)

Pollutants	**Health Impact**
Carbon monoxide	Low birth weight Increased perinatal death
Nitrogen dioxide	Asthma Respiratory infection Reduced lung function
Sulfur dioxide	Asthma Exacerbation of COPD Cardiovascular diseases
Polycyclic aromatic hydrocarbons	Lung cancer Cancer of mouth Nasopharynx Larynx
Particles	Asthma Respiratory infection Chronic bronchitis COPD

2.4 Indoor Air Quality and Architecture

There are many architectural and design elements that could affect the indoor air quality of residential spaces. However, two main aspects have been chosen for this thesis in order to assess their specific correlation with the measurement and the lifestyle factors.

2.4.1 Natural and Cross Ventilation

Ventilation is one of the most important factors that are taken into consideration in any living environment. Since the ancient times, the early human adopted natural ventilation techniques driven by wind in order to keep the indoor environment at a comfortable temperature level and renew fresh air in closed spaces by using stack ventilation that is observed in many old building designs as the motorized technology was not available at that time (Ismail & Abdulrahman, 2012), as seen in Figure 2.3. Nonetheless, due to the spread of compact and modern house designs, cross ventilation has become the most economic and effective way to reduce pollutants in the indoor environment, especially houses.

Figure 2.3: Wind towers for stack ventilation in ancient houses in the Arab Region (The City, 2013)

There are two factors that affect the effectiveness of cross ventilation in any space, which are the effective opening area and the orientation of the openings. In a study that involved 32 spaces in Thailand, the authors researched the most effective cross ventilation orientation within the selected case studies using a CFD model. The opening orientations were divided into three main categories, Figure 2.4 show the different types of opening orientations (Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007):

1. Cross ventilation
2. Two-sided ventilation
3. One-sided ventilation

Moreover, the openings size is calculated as a percentage from the flooring area. Thereafter, the CFD model was applied and a scoring scale is developed to judge the effectiveness of ventilation in the case study spaces, as shown in Table 2.11 below.

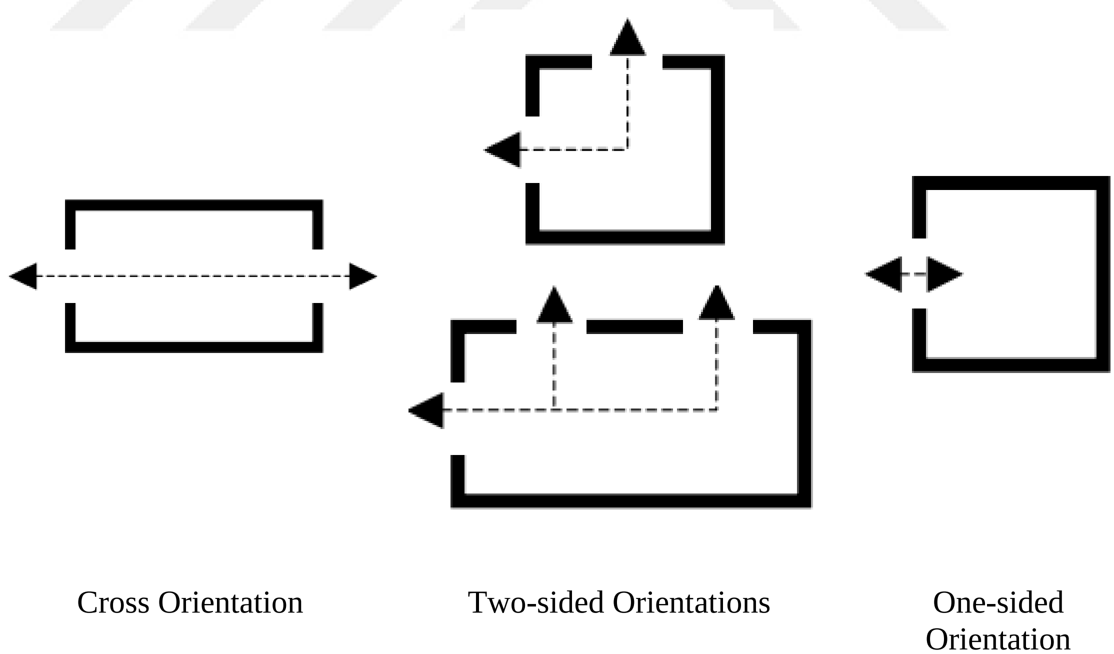

Figure 2.4: Types of orientations of openings (Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007)

Table 2.11: Rating of natural ventilation (Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007)

Rating	Score	Criteria			
		Openings orientation			Effective Opening Areas (%)
		Cross	Two-Sided	One-Sided	
Good	≥ 3.00	●	●		14.36 – 20.46
Satisfactory	2.50 – 2.99	●	●		10.42-15.50
			●		15.31-19.80
Fair	2.00 – 2.49	●	●		12.14-12.92
			●		14.38 – 16.16
		●	●	●	16.25
Poor	< 2.00		●		11.45
		●	●	●	11.35

The study concluded that the best type to achieve effective ventilation is by using the cross orientation, combining it with an optimum opening percentage of 20% of the functional floor area, which optimizes the wind velocity running though the space (Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007).

2.4.2 Building Material

As reviewed earlier in previous sections, most of the dangerous pollutants in the indoor environment are generated by building material. Achieving an architectural design that supports a high or at least acceptable indoor air quality starts at the early design stage, when the design strategy is determined. However, there are many challenges that face designers in achieving a design that empowers indoor air quality including budgets and client awareness (Senitkova, 2017).

Furthermore, in a Danish study that involved constructing two model rooms, one with low polluting material and the other one is built using high polluting material, an experiment was conducted to examine the perceived air quality by letting 50 students to identify their acceptability of the material in different room depending on their comfort.

The setting of the experiment consisted of two rooms; a glass chamber that contained samples of ventilated low polluting material, and a test room that was initially constructed with high polluting material. Thereafter, the test room materials were substituted with low polluting material in a second round of the survey. The participants were able to identify the material that made them feel uncomfortable in each round of the experiment, which indicates that a person can distinguish the space based on the comfort towards the air quality (Wargocki, Knudsen, & Zuczek, 2007).

Due to the importance of the subject and the dominant contribution of the building material to the indoor air quality, the field specialists, including architects and designers, established many systems and frameworks in order to be able to provide building material that achieves a high indoor air quality. Thus, it was found that paint, adhesives and sealants are the most common source of pollution in indoor environments (Lee, Kwon, Joo, Kim, & Kim, 2012). Table 2.12 provides the material grade standards for these materials according to different pollutants they emit.

Table 2.12: Material grading according to pollutants' emission (Lee, Kwon, Joo, Kim, & Kim, 2012)

Grade	Pollutants	Building material, paint and putty (mg/ m^2 h)	Adhesives (mg/ m^2 h)	Sealants (mg/ m^2 h)
Best	Total VOC	< 0.10	< 0.10	< 0.25
	5 VOC	< 0.03	< 0.03	< 0.75
	HCHO	< 0.015	< 0.015	< 0.015
Excellent	Total VOC	> 0.10 & < 0.20	> 0.10 & < 0.30	> 0.25 & < 0.75
	5 VOC	< 0.06	< 0.09	< 0.22
	HCHO	> 0.015 & < 0.05	> 0.015 & < 0.05	> 0.015 & < 0.05
Satisfactory	Total VOC	> 0.20 & < 0.40	> 0.30 & < 0.60	> 0.75 & < 2.5
	5 VOC	< 0.12	< 0.18	< 0.75
	HCHO	> 0.05 & < 0.12	> 0.05 & < 0.12	> 0.05 & < 0.12

5 VOC = benzene, toluene, ethyl benzene, xylene & styrene
HCHO = formaldehyde

2.5 Indoor Air Quality Measurement

There are several ways that were used throughout the studies to measure the indoor air quality. Most of the studies adopted a hybrid approach by performing actual measurement on the concentration of pollutants in the targeted environment and surveying the opinions of the space occupants. A study by the Chartered Institute of Environmental Health in Northern Ireland was commenced by measuring the concentration of $PM_{2.5}$ and Nicotine in bars before and after passing a no-smoking legislation in the province by using a pollutant measuring device. Thereafter, the study performed a survey questionnaire on 51 of the staff who worked in these spaces. Figures 2.5 shows the results of the workers' assessment of the indoor air quality before and after the legislation (Grimley, Evans, Mulcahy, McFarlane, & Gilmore, 2010).

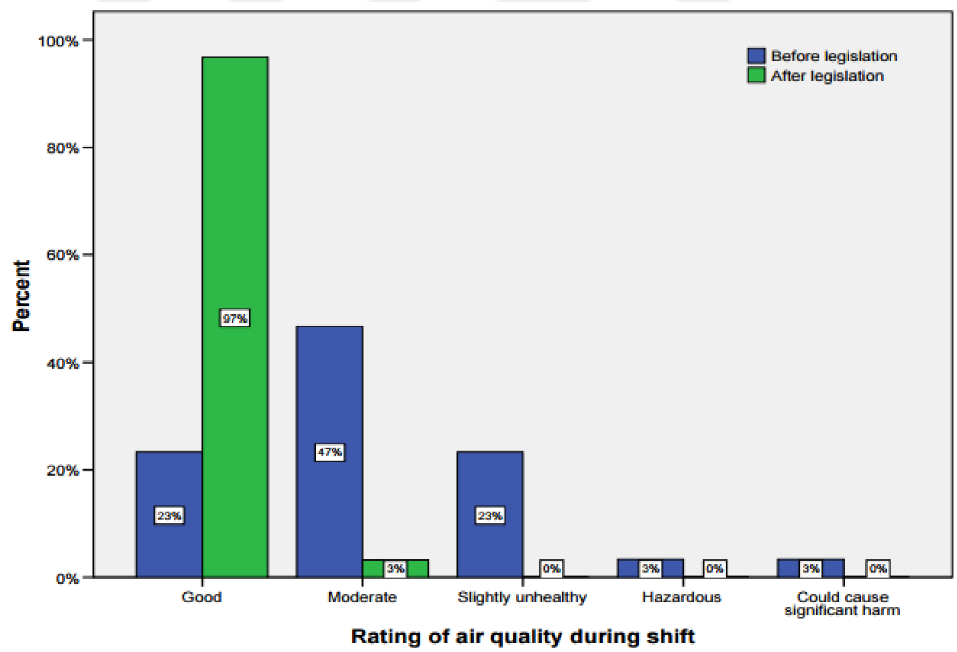

Figure 2.5: Assessment of workers for IAQ before and after smoking (Grimley, Evans, Mulcahy, McFarlane, & Gilmore, 2010)

A study performed on students in a higher education institution in Malaysia used a pure survey methodology in order to measure the perception of the occupants of the indoor environmental quality, which the indoor air quality formed an essential part of it. In order to reduce the impact of pollutants on their health, 90% of the students indicated that they would use masks or open windows for ventilation and fresh air (Sulaiman, Wan Yusoff, Pawi, & Wan Kamarudin, 2013).

From the above examples, the measurement and questionnaire methodologies are both adopted in evaluating the indoor air quality in different spaces. Nonetheless, this study will use both methodologies, in addition to design observation criteria, which are cross ventilation and building material.

2.6 Lifestyle of Arabic People

The Arabic culture is unique than the different cultures that surrounds it due to the many factors that contributes into forming its social elements and lifestyle. In a study that included 50 individuals from different Arabic countries, it was found that while it is acceptable for women to smoke tobacco in some Arabic cultures, such as Jordan and Lebanon, it is considered unacceptable for them to smoke in more conservative Arabic cultures. Moreover, the study shows the impact of the different cultural backgrounds on the lifestyle adapted including diet, social courtesy and physical activities (Donnelly, et al., 2011). As a form of hospitality, the Arabic culture has the habit of scenting the home before the arrival of guests by burning scented wood (Sobh & Belk, 2011).

Moreover, studies show that the Islamic values have a great influence on the Arabic culture lifestyle and social values (Ezzi, Teal, & Izzo, 2014). Furthermore, in the Arabic family, performing house cooking and regular cleaning are usual habits that are carried out in the household. Several households adopt indoor plantation due to its positive effects and the positive emotions associated with greenery (Lohr, 2010). There are several habits that are associated with the Arabic lifestyle that affect the indoor air quality, as shown in Funk, et al. (2014). The hot climate that dominates most of the Arabic countries, especially in the summer season, requires using air conditioning and lowers the chances for natural air ventilation, which has its implications on indoor air quality (Funk, et al., 2014).

3. METHODOLOGY

3.1 Study Objectives

The aim of this research is; to evaluate the indoor air quality in the houses of the Arab residents in Ankara using actual pollutants' measurements and considering their lifestyle habits and the architectural design of their houses.

The objectives of the research are as the following:

1. To measure the concentration of pollutants in the houses of Arab residents in Ankara.
2. To survey the lifestyle of the Arab residents in Ankara including their cleaning, cooking, smoking habits and usage of indoor plants.
3. To study the architectural design of the houses of Arab residents in Ankara in terms of cross ventilation and finishing material.
4. To evaluate the relationship between indoor air quality measurements and lifestyle of occupants.
5. To evaluate the relationship between indoor air quality measurements and the architectural design of the houses, i.e. cross ventilation and finishing material.
6. To measure the level of indoor air quality of the Arab residents who are living in Ankara and agreed to take part in this research.
7. To provide recommendations to enhance indoor air quality in the houses of Arab residents in Ankara and to the city residents in general based on lifestyle habits and architectural design parameters.

3.2 Hypotheses

The hypotheses of the research are established as the following:

H1: There is a correlation between presence of cross ventilation in the houses of the Arab residents in Ankara and the measured pollutants' level.

H2: There is a correlation between the cleaning habits of the Arab residents in Ankara and the indoor air quality in their houses.

H3: There is a correlation between the cooking habits of the Arab residents in Ankara and the indoor air quality in their houses.

H4: There is a correlation between the presence of indoor plantation of the Arab residents in Ankara and the indoor air quality in their houses.

H5: There is a correlation between tobacco smoking habit of the Arab residents in Ankara and the indoor air quality in their houses.

H6: The Arab residents in Ankara have high satisfaction regarding indoor air quality in their houses.

H7: The level of IAQ is acceptable through pollutant measurement is acceptable according to IAQ standards.

3.3 Study Methodology

Gathering the data for this research is performed through a field visit to the houses of the Arab residents in Ankara. A potential participants' list is developed and appointments are specified for house visits. At the appointment, the researcher followed the below procedure:

1. The researcher commences his survey by studying the architectural design of the house to assess cross ventilation and the building material of the house. An approximate window to floor area ratio is noted. Moreover, the main building materials are noted including the finishing material for the floors, walls and ceilings.
2. Pollutants' measurements are taken using the VOC meter for total VOC measurements, as well as CO and CO_2 measurement using a pollutant measuring device.

3. An occupant of the house takes the designed survey in order to assess the household lifestyle and perceived indoor air quality.

After gathering data, SPSS is used to record the data and perform the required analysis. Finally, based on the results of the survey, the correlations between the different factors are studied and the results are discussed by providing recommendations and conclusions. Figure 3.1 provides an illustration of the study methodology.

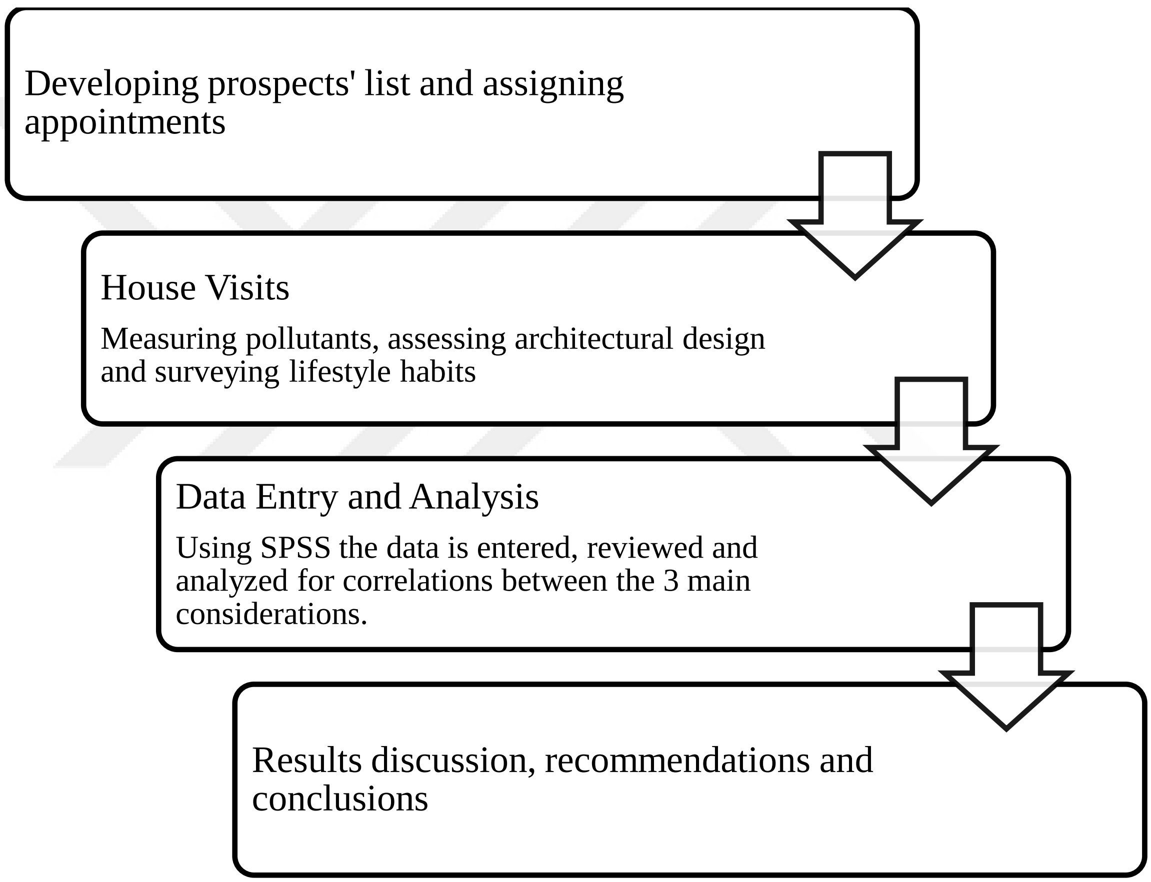

Figure 3.1: Illustration of Study methodology

3.4 Research Design

The research will use both qualitative and quantitative methods to measure the indoor air quality in the houses of Arab residents in Ankara, and establish the relations between the following parameters:

1. The concentration of pollutants: measured in ppm and μg/m3
2. The architectural design of the house: cross ventilation evaluated for its existence and approximated as a percentage of openings to the floor area, and building material is surveyed.
3. The lifestyle habits of the occupants: four parameters are considered, which are:
    a. Cleaning: types of material used and regularity.
    b. Cooking: Frequency of cooking and availability of ventilation in the kitchen.
    c. Plantation: availability of indoor plantation.
    d. Smoking: availability of smoking in the house indoor environment.

Furthermore, each part of the case study procedures, sampling and analysis techniques are elaborated in the below sections.

3.4.1 Cross Ventilation and Finishing Materials Survey Design

This part of the field survey is constructed into two parts:

1. Evaluating cross ventilation

The evaluation of cross ventilation is performed through investigating if the examined house has two or more openings that are opposite to each other. This parameter falls under the researcher’s judgement by answering the data sheet (Appendix 1) with one of three answers; Available, partially available, not available. The partially available choice is selected if two-sided openings are available and the distance between them is significant. Moreover, the researcher will measure the window sizes, where the cross ventilation occurs, and form a ratio to the floor area between the two openings. According to (Tantasavasdi, Jareemit, Suwanchaiskul, & Naklada, 2007), a ratio of 0.2 and above is considered as effective cross ventilation, while other ratios can follow the judgement based on Table 2.11.

2. Finishing materials

Surveying the finishing materials is performed through a direct notation by the researcher of the finishing material of the floor, wall and ceiling. The range of the choices is as shown in the data sheet (Appendix 1). In addition, the researcher will ask the house occupant two key questions (Mantanis, Vouli, Gonitsioti, & Ntalos, 2007):

a. Have any maintenance activities been performed in the past 6 months, including painting, plastering, using adhesive material, and installing wooden material?
b. Have the household purchased any brand-new casework or furniture in the past 6 months?

Both questions will be answered by either Yes or No.

3.4.2 Architectural Assessment and Pollutants Measurement Design

In this research, selected architectural characteristics are chosen in order to understand the relationship between them, and the subjective and objective measurements of the indoor air quality, which are:

1. Cross ventilation
2. Finishing material (Floor, wall, ceiling, window and door frames)
3. Total room numbers
4. House floor
5. Façade sides and orientation
6. Closeness to the main road

Furthermore, other information is also collected, including the performance of maintenance activities within the past 6 months, purchasing brand-new casework or furniture in the past 6 months, and the if the house if laying on a main road. In the second part of the datasheet measurements of pollutants are recorded, including total VOC, CO and CO_2, using the devices shown in Figure 3.2. Moreover, Figure 3.3 shows other material used in measurement, including measuring tape, compass and laser distance measuring device. The first device is used for the measurement of the Total

VOC (MultiRAE Lite, Model: RAE3775), while the second device measures the CO and CO_2 levels (RAE Pro PID by RAE Systems, Model: ToxiRAE Pro PGM-1800). Both devices are capable of providing the specified pollutants' measurements over a set period of time. Therefore, minimum, maximum and mean readings can be provided at the end of each measurement.

Figure 3.2: Devices used for total VOC measurement (left: RAE3775), and CO and CO_2 measurements (right: ToxiRAE Pro PGM-1800)

Figure 3.3: Devices used for distance, area and orientation measurements (Measuring tape, compass, laser distance measuring device)

3.4.3 Occupants' Questionnaire Design

The last step of the data collection in a household is the questionnaire survey, which could be filled directly by the occupant or assisted by the researcher. The occupants' questionnaire template is available in Appendix 2, and divided into four main parts:

1. Demographics and household data

The purpose of this part is to evaluate the number of people affected by the current indoor environment, by collecting information that includes the gender of the participant, the number of people living in the house environment, marital status and age category.

2. Household health evaluation

The participant household is asked about the regularity of sickness in the family through three questions. How often do you get sick per year? (Answers: 0 to 1, 2 to 3, 4 to 5, and 6 times and more), Are there any chronic diseases within the family, Cancer and Asthma mainly? (Answers: Yes, and No), and Do any of the family members suffer from skin irritations, eye, nose or ears infections or allergies, lung infections? (Answers: Yes, and No). This evaluation intends to form an idea about the general health of the family in order to analyze it against the results of the indoor air quality measurements.

3. Lifestyle habits evaluation

The participant household is asked about their lifestyle and habits that may affect the indoor air quality as the following:

a. The regularity of the cooking activities in the house and the availability of ventilation mechanisms in the kitchen and its type.
b. The regularity of the cleaning activities in the house and the type of material and agents used in cleaning.
c. The availability of indoor plantation.
d. The availability of smoking within the house indoor environment.

4. Indoor Air Quality Perception and Satisfaction

The participant household is finally asked about their overall satisfaction of the indoor air quality by using a 6-point Likert scale (very satisfied, satisfied, normal, unsatisfied, very unsatisfied). Moreover, the participants are also asked to provide their perception of the indoor air quality using a 6-point Likert scale (very good, good, slightly good, slightly bad, bad, very bad).

3.4.4 Sample and Study Limitations

The households are selected from the Arab community residing in Ankara Turkey. The target of the researcher is to perform the study in 20 households of different Arab nationalities (Libyan, Syrian, Iraqi and Jordanian) in order to ensure a collective sample from the available population. As of 2016, statistics shows that there are 2.6 million Arabs living in Turkey, which approximates the total population in Ankara to around 165,000 Arab people (Coffey, 2016). According to Turkish Statistical Institute, the average size of a household is 3.8 (Turkstat, 2013). Therefore, the sample size is 0.046%.

There are several limitations to the study, which are mentioned as a source of possible errors related to the sampling:

1. The prospect list is made through personal connections, which may not enable the researcher to distribute the surveyed household according to the Arab nationalities' representation in Ankara.
2. The appointments are made through phone calls and are subject to approval or rejection.
3. The information in the questionnaire represent the responses one of the occupants in the household, which makes the provided information subject to his or her judgement.

3.4.5 Data Analysis

The collected data from the three parts of the survey and measurements are entered to IBM SPSS Statistics and then analyzed using correlation and variance testing in order to establish the relationship between the different factors of pollutants measurement, architectural elements and different lifestyle elements. The Alpha value for means is set at 0.05.

4. FINDINGS, ANALYSIS AND DISCUSSION

Based on the households' visits that are conducted in this study, this chapter provides a descriptive narration of the findings of the architectural characteristics, objective measurements and questionnaire. The aim is to understand the influence of the different aspects on each other.

4.1 Findings

The descriptive findings of the research are divided into several sections according to their type. The section starts with an architectural assessment of the households, studying their cross ventilation, finishing material, areas, façade orientation, and closeness from a main road. Moreover, other factors are taken into consideration, such as; maintenance activities and purchasing of brand-new furniture and casework. The results of the objective measurements are also provided for further correlation in the following section. Moreover, the questionnaire results with four parts are provided, including the demographics of the household, health evaluation, lifestyle evaluation and IAQ perception.

4.1.1 Architectural Assessment and Measurement of Pollutants

All the surveyed households have varied types of natural ventilation possibilities; however, only 35.0% have a proper cross-ventilation, while 45.0% and 20.0% have two-sided and one-sided ventilation, respectively, as shown in Figure 4.1. In regard to the finishing material used in the living room, all households' living rooms had wood laminates as their finishing, while all walls were painted. All households' ceiling finishes are also paint, except for one household which had a wooden ceiling panel. Furthermore, 75% of the window frames were of an aluminum type, while the rest were wooden. On the contrary, 90% of the households' door frames were wooden, while the rest were aluminum. Moreover, Figures 4.2 and 4.3 show histograms of the living room floor areas and living room window areas respectively. The mean area of the living rooms is 27.6 m^2, with a minimum of 18.50 m^2 and a maximum of 41.80 m^2. The mean area of the windows is 1.64 m^2, with a minimum of 0.68 m^2 and a maximum of 2.84 m^2.

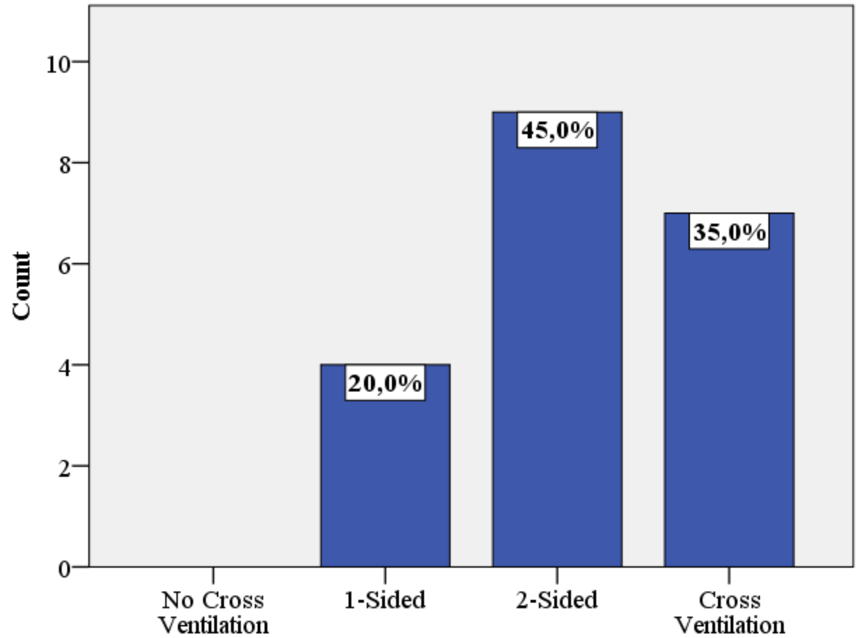

Figure 4.1: Ventilation type in the surveyed houses

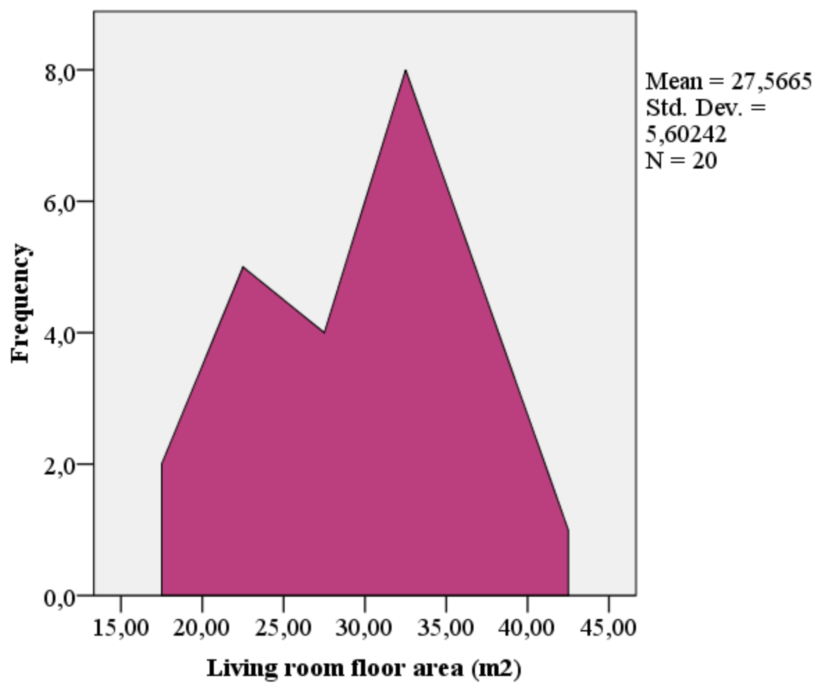

Figure 4.2: Living room floor area histogram

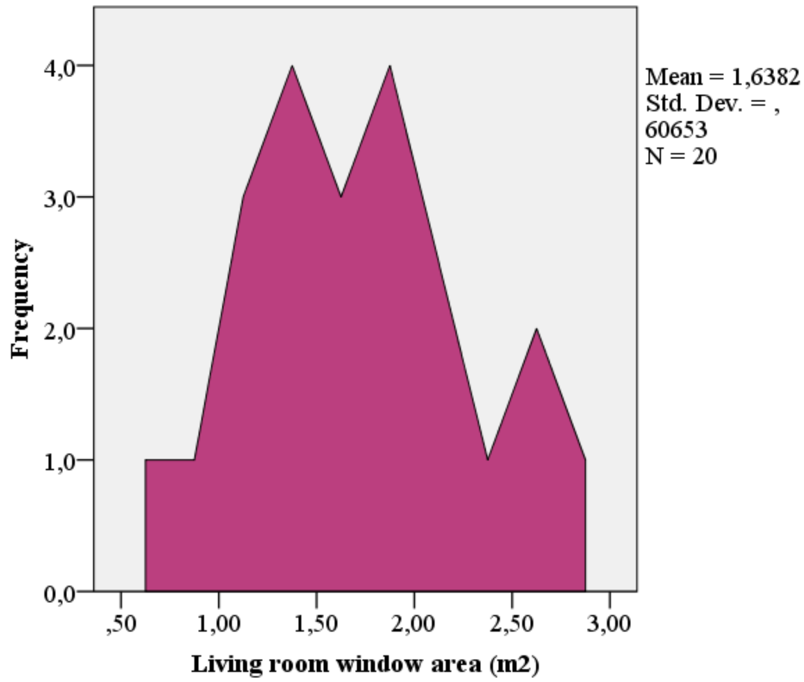

Figure 4.3: Living room window area histogram

Furthermore, 85% of the case study households consist of three bedrooms, in addition to a living room, a kitchen and one or two toilets. One case had a maintenance conducted in the past six months and another case had purchased brand-new furniture within the same period. 25% of the case studies lay on a main road, while the floor in which the apartments are located in is shown in Figure 4.4. The majority of the case studies are located in the ground and second floors. Moreover, Table 4.1 shows the façade orientation of the households of the case study. The majority of the case studies are mostly oriented towards the West then the South, respectively. Detailed information on each observed house for this study is presented in Appendix 3.

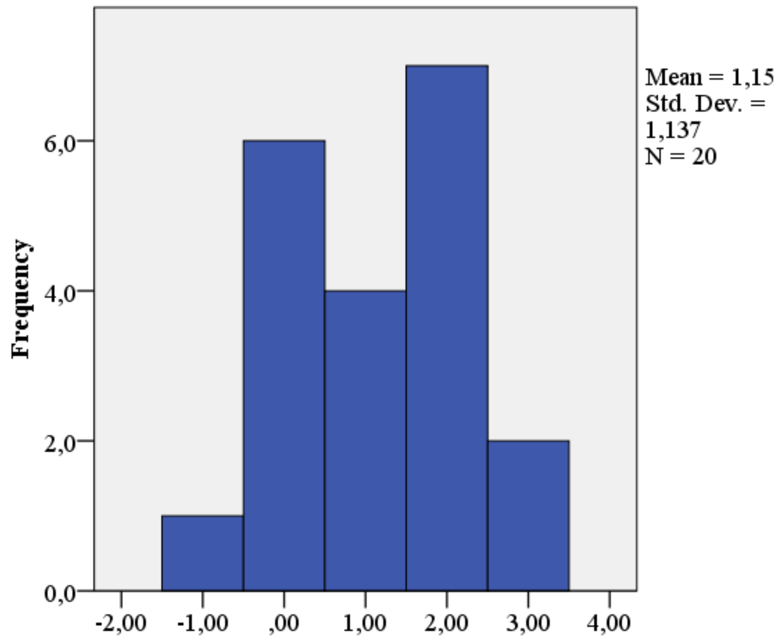

Figure 4.4: Case study households floor location

Table 4.1: House Facade orientation of the case study households

Household	Facade Orientation							
	E	N	W	S	NE	NW	SE	SW
1		●	●	●				
2		●	●	●				
3			●	●				
4						●	●	
5					●			●
6		●	●					
7		●	●					
8	●		●					
9			●	●				
10	●		●	●				
11			●	●				
12		●	●	●				
13		●						●
14			●					
15			●	●				
16	●	●						
17			●	●				
18	●		●	●				
19	●			●				
20	●			●				

In regard to the pollutant measurements in the case study houseolds, 40% have shown no total VOC readings, while 70% have shown no CO readings. However, all households have shown different level of readings for CO_2. Figures 4.5, 4.6, and 4.7 show the total VOC, mean CO and mean CO_2 readings histograms, respectively. The mean total VOC reading is 0.145 ppm, and 0.7 ppm and 965 ppm for CO and CO_2, respectivly. The houses that have high levels of total VOC and CO levels are noted to be performing cleaning activities including floor cleaning, and clothes' washing using a washing machine. The researcher observed that these activities have contributed into the readings, while further evidence is seeked through the correlational analysis in the next section. The mean readings of the CO and CO_2 are below the limits of 9 ppm and 970 ppm, respectively, which are set by ASHRAE and NAAQS standards. The Total VOC mean of 0.145 ppm (145 ppb) is close to the maximum limit of 120 ppb, which indicate acceptable indoor air quality along with the results of CO and CO2 (Safetech, 2014).

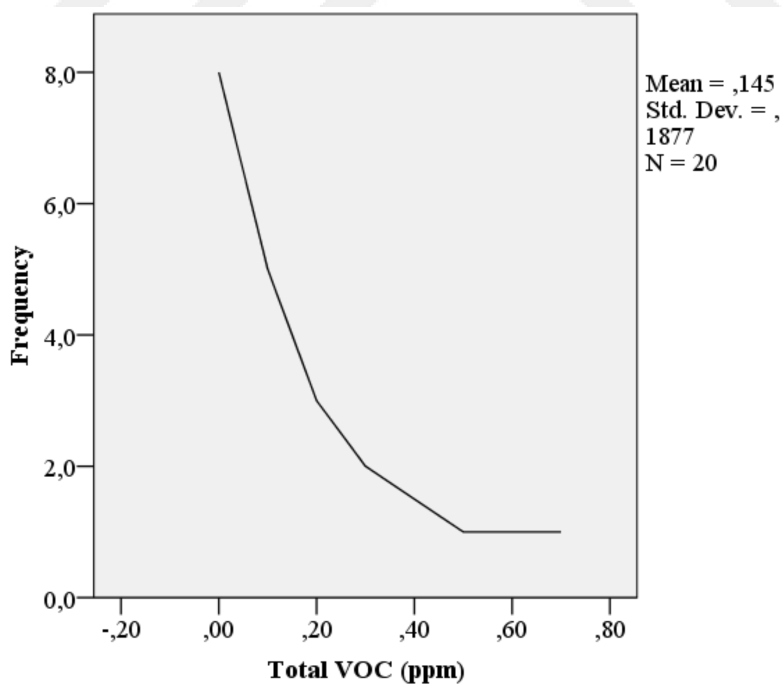

Figure 4.5: Histogram for total VOC readings in case study households

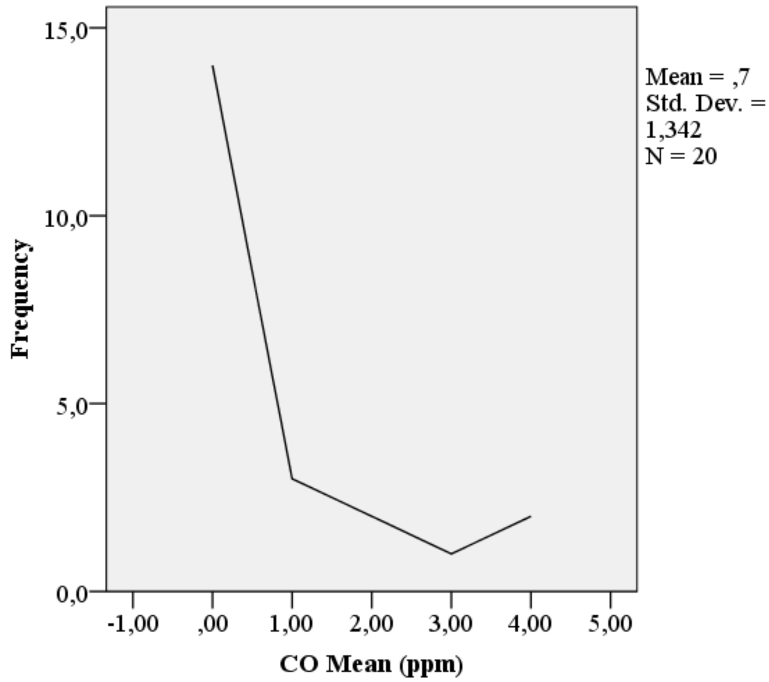

Figure 4.6: Histogram for mean CO readings in case study households

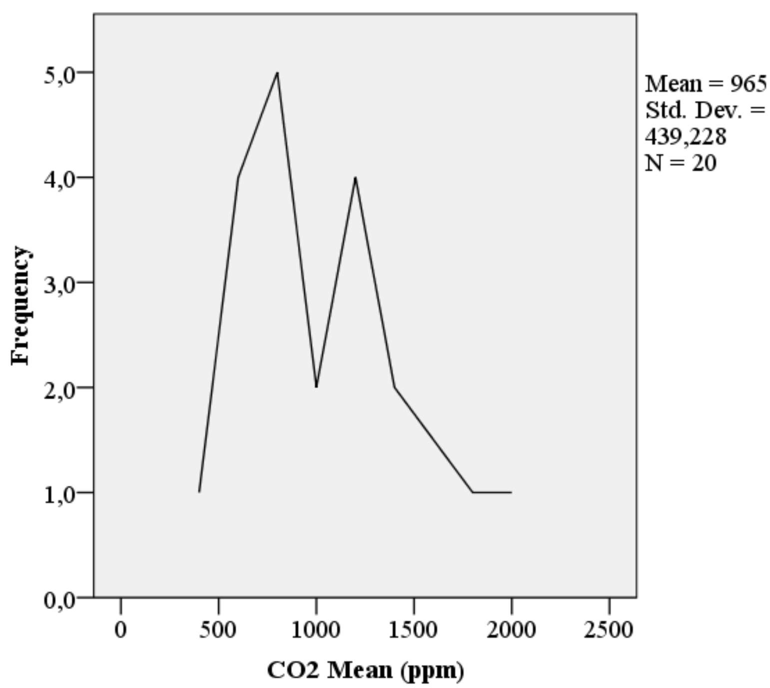

Figure 4.7: Histogram for mean CO_2 readings in case study households

4.1.2 Questionnaire Results

The questionnaire is divided into four parts; demographics, health evaluation, lifestyle evaluation and IAQ perception and satisfaction. The questions are designed in order to correlate them with the findings of the architectural assessment and objective measurements that were reviewed in the previous section.

4.1.2.1 Demographics

As the questionnaires are taken by one member of the family, who is mostly the head of the household in Arab culture, 90% of the participants were male, as shown in Figure 4.8. Moreover, the average number of people living in the household is 4.3 persons, with 55% of the households having five people and more, as shown in Figure 4.9. The high average of people in the household is explained by the marital status, as 80% of the participants are married, as shown in Figure 4.10. Moreover, 85% of the participants have an age category between 30 and 40 years.

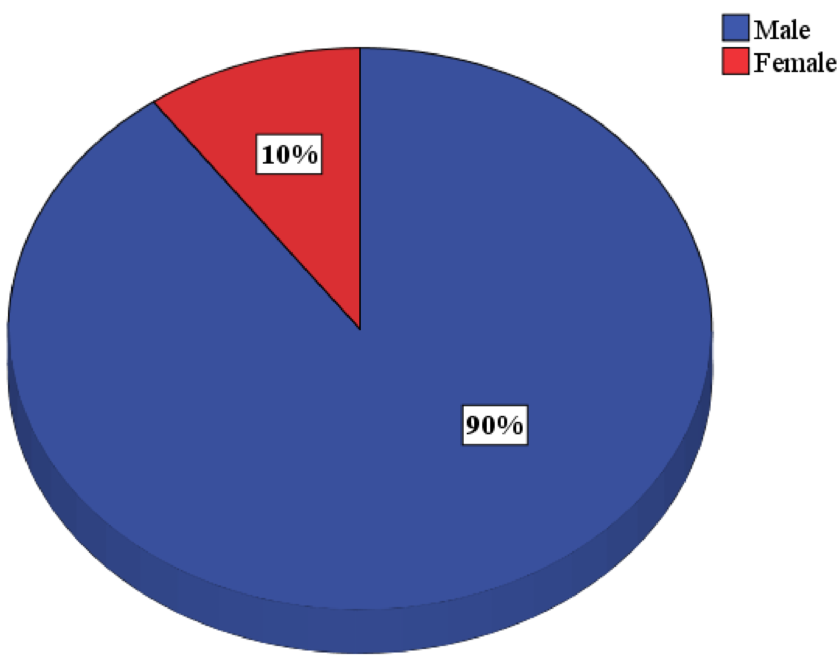

Figure 4.8: Gender of the participants

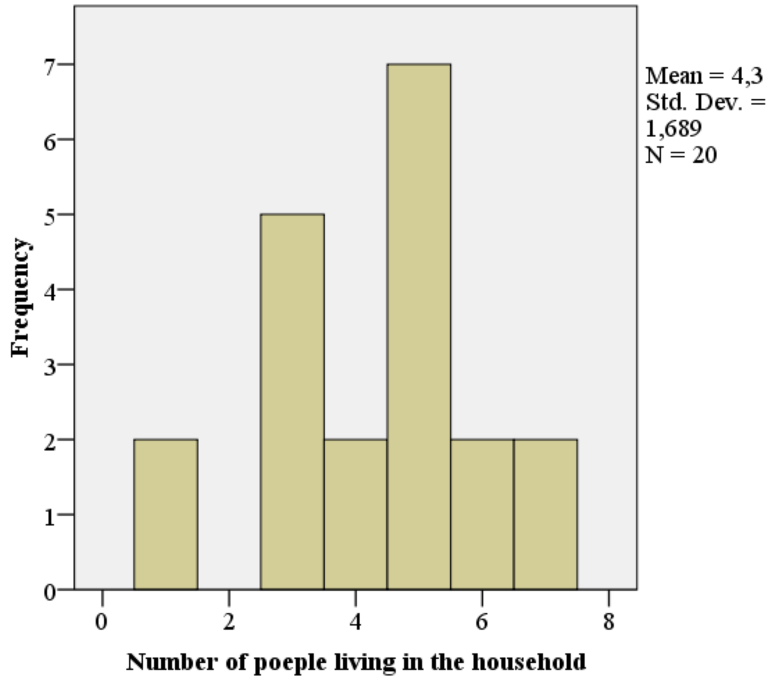

Figure 4.9: Histogram for number of people living in the case study households

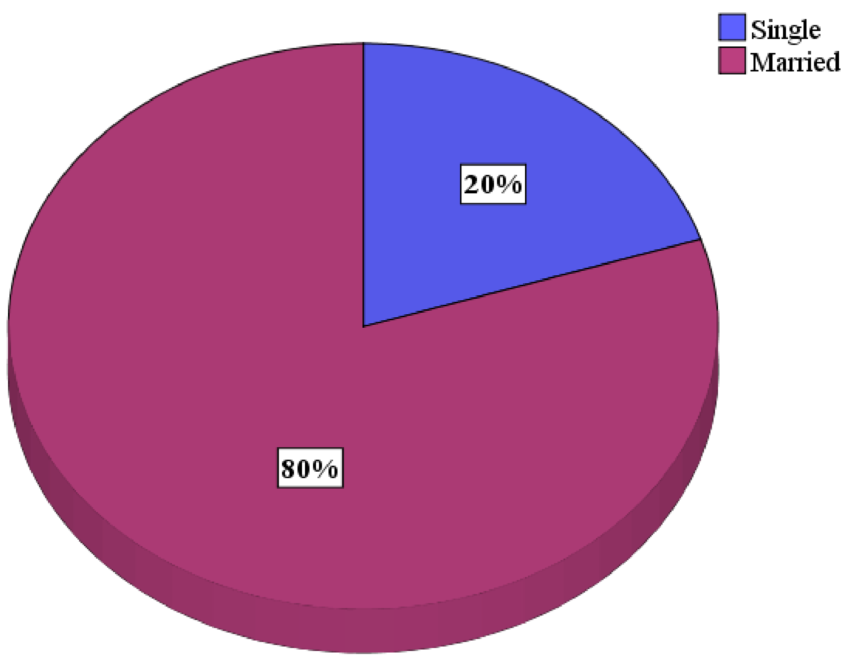

Figure 4.10: Marital Status of the participants

4.1.2.2 Heath Evaluation

The participants have indicated that 50% of them get sick two to three times per year, as shown in Figure 4.11, while the rest do not get sick often or get sick once per year. One participant has indicated the existence of a chronic disease within the household. Four participants have stated that them or a member of their family have allergies. Furthermore, 30% of the participants have indicated that they or a member of their household smoke tobacco.

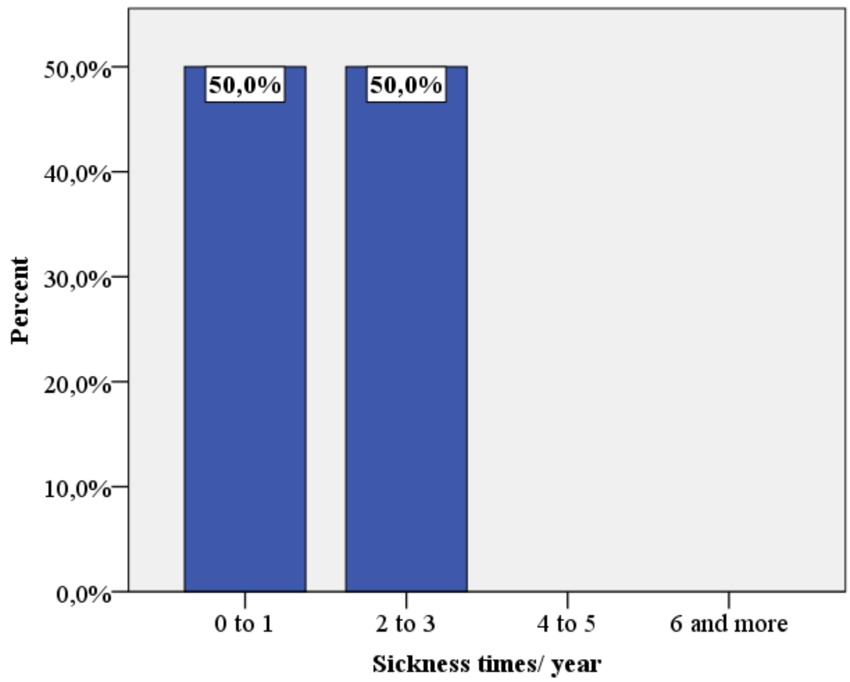

Figure 4.11: Number of sickness days per year

4.1.2.3 Lifestyle Evaluation

Four aspects of the household lifestyle are investigated in this section; cooking, cleaning, indoor plantation, and allowing smoking within the house or the living room. 90% of the participants indicated that they cook daily in the household, while the rest showed that they cook at least 3 times per week. As shown in Figure 4.12, 95% of the households have either small windows or cooker hood as a ventilation method in their kitchens. Furthermore, 95% of the households showed that they clean more than three times per week, as shown in Figure 4.13, and they are using chemical agents in performing this task. While none of the households showed that they have indoor plantations, only 15% indicated that they allow smoking in the house or in the living room.

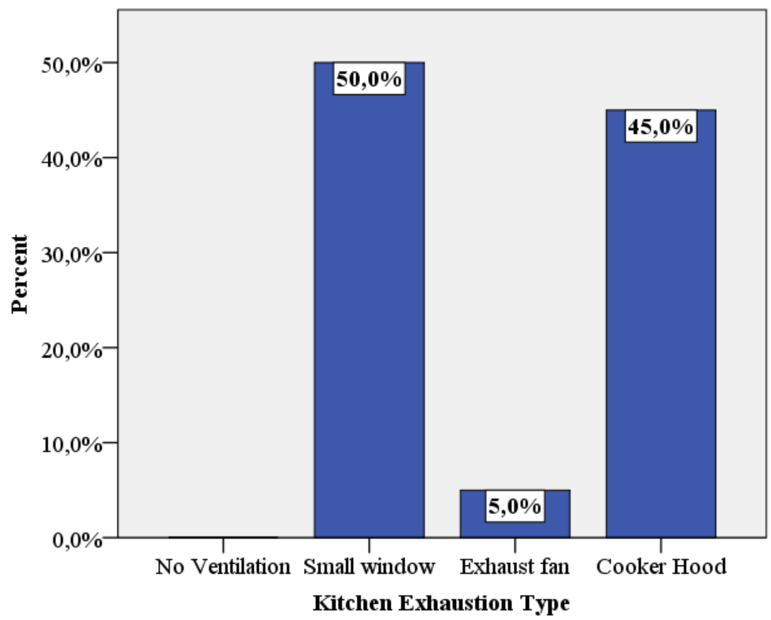

Figure 4.12: Exhaustion type used in the kitchens of the participating households

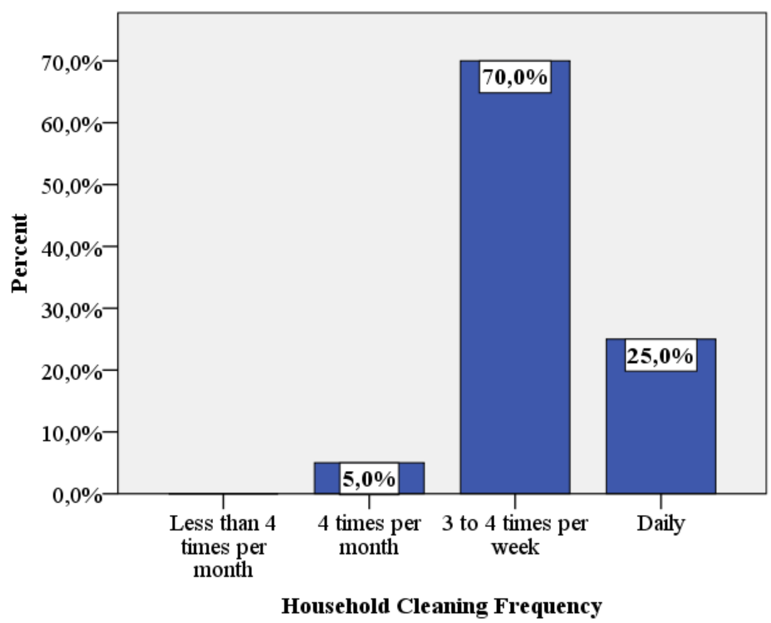

Figure 4.13: Number of times cleaning of participating households

4.1.2.4 Indoor Air Quality Perception and Satisfaction

The participants have shown that they perceive the indoor air quality of their household with medium to high satisfaction, as shown in Figure 4.14. Furthermore, Figure 4.15 show that the participants are generally satisfied with different degrees from the IAQ in their households. The perception represents an evaluation of the residents of the indoor air quality, while the satisfaction shows the level of acceptance of the current IAQ condition.

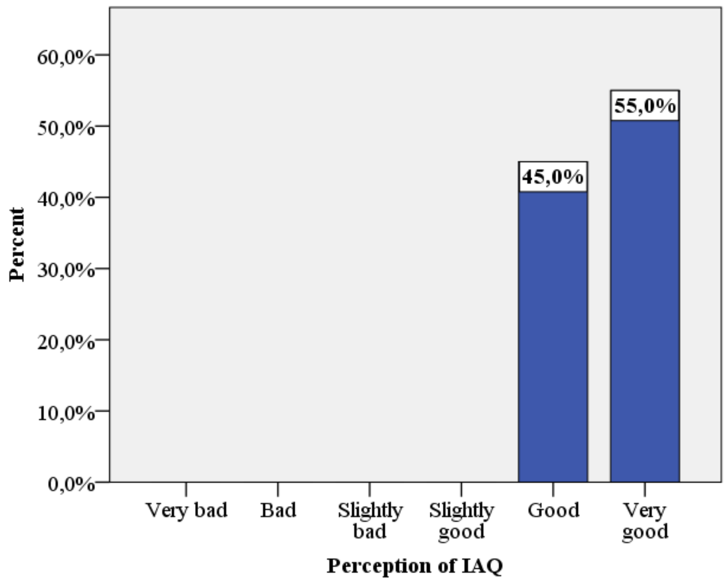

Figure 4.14: Perception of indoor air quality in user's house.

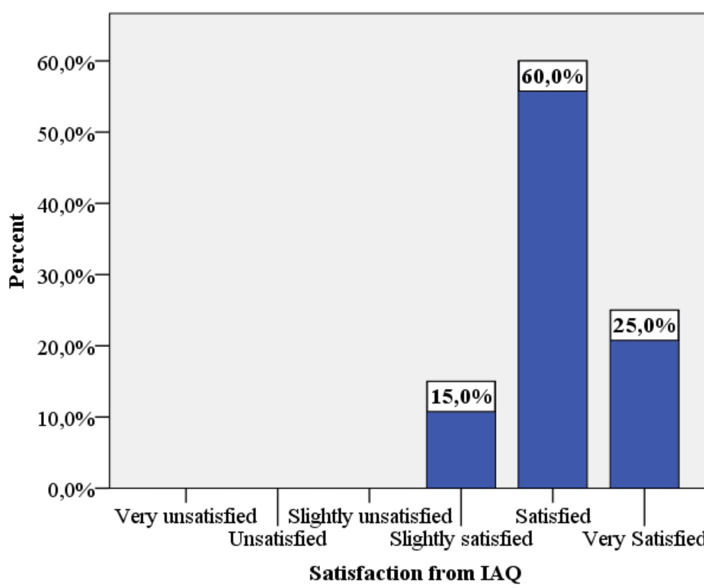

Figure 4.15: Satisfaction from indoor air quality in user's house.

4.2 Analysis and Discussion

Using Spearman's rho correlation, the analysis of the results shows a weak correlation between cross-ventilation and the objective pollutant measurements of the households. Moreover, the different objective measurements show moderate to strong correlation between the different types of readings, as shown in Table 4.2. These results show that the higher the degree of cross ventilation adopted in the design of the house, the less total VOC within the indoor environment. However, positive correlations with the readings of the CO and CO2 with the increase of cross ventilation are mainly attributed to the impact of the road traffic emissions that enter the house more efficiently through a higher airflow from the outside to the inside of the house.

Table 4.2: Spearman rho correlations between cross-ventilation and pollutant measurements in the participating households ($p<0.05$)

	1	2	3	4	5	6	7	8
1. Cross ventilation	1.000							
2. Total VOC	-0.222*	1.000						
3. CO Mean	0.241*	0.493**	1.000					
4. CO Min	0.247*	0.487*	0.998**	1.000				
5. CO Peak	0.247*	0.487*	0.998**	1.000**	1.000			
6. CO_2 Mean	-0.41	0.704**	0.586**	0.596**	0.596**	1.000		
7. CO_2 Min	0.180	0.663**	0.661**	0.671**	0.671**	0.908**	1.000	
8. CO_2 Peak	0.251*	0.629**	0.656**	0.667**	0.667**	0.888**	0.980**	1.000

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

The finishing material used in the Arab residents in Ankara did not show apparent variances. Therefore, there were no correlations between the finishing material and the objective measurements of the pollutants. However, a moderate correlation of 0.353 (Significant at the 0.05 level 2-tailed) is found between performing maintenance activities within the past six months and the total VOC readings, which confirms the findings of Mantanis et al. (2007) that showed that recent maintenance and casework activities increase the total VOC level within the indoor environment. Futhermore, weak to moderate correlations were found between the effectiveness of cross-ventilation and the sickness frequency, chronic diseases and allergies in the household. High moderate correlations were found between cross-ventilation, and a better IAQ perception and high IAQ satisfaction. Those results are provided by testing spearman's rho correlation, as shown in Table 4.3.

Table 4.3: Spearman rho correlations between cross-ventilation and health evaluation, and IAQ perception and satisfaction ($p<0.05$)

	1	2	3	4	5	6
1. Cross ventilation	1.000					
2. Sickness frequency	-0.467*	1.000				
3. Chronic diseases	-0.064	-0.229*	1.000			
4. Allergies	-0.444*	0.250*	0.459*	1.000		
5. IAQ Perception	0.470*	-0.503*	0.208*	-0.302*	1.000	
6. IAQ Satisfaction	0.301*	-0.327*	-0.045	-0.285*	0.627**	1.000

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

Correlating objective pollutants' measurements and the lifestyle habits of the occupants collected through the questionnaire answers, spearman rho relationship testing was performed for four indicators; cooking and kitchen ventilation, cleaning frequency and cleaning material, and smoking in the indoor environment. No correlation could be tested for the interior plantation, as none of the participating households had interior plantation. For the cooking frequency, as shown in Table 4.4, households who cook more often showed a moderate correlation with total VOC, CO and CO_2 readings. The strongest correlation is found with the CO_2 readings, which could be a result to inadequate ventilation methods in the kitchen, as recommended by WHO (2014). Moreover, the type of ventilation used in the kitchen has shown a weak to moderate correlation with the pollutants' measurements; however, the correlation factors show a positive factor indicating that open windows are more efficient in ventilation than cooker hoods. This indicates that using the cooker hood is not necessarily the best method to ventilate the interior environment from the combustion gases including CO and CO_2.

Table 4.4: Spearman rho correlations between cooking (frequency and ventilation) and pollutant measurements ($p<0.05$)

Pollutants' Readings	Cooking frequency	Kitchen Ventilation Type
Total VOC	0.362*	0.144
CO Mean	0.214*	0.197
CO Min	0.214*	0.207*
CO Peak	0.214*	0.207*
CO_2 Mean	0.380*	0.270*
CO_2 Min	0.451**	0.453**
CO_2 Peak	0.421**	0.483**

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

Furthermore, the cleaning habits, especially the material used, has its effects in increasing the VOC content of the indoor environment, as shown in Table 4.5. Therefore, spearman rho correlation testing is conducted between the pollutant measurements and the cleaning habits' indicators included in the questionnaire. The cleaning frequency did not yield any significant correlations, while the type of material used for cleaning showed a weak correlation with total VOC and CO_2 readings. The positive correlation indicates that using chemical agents in cleaning increases the total VOC in the indoor environment, as reviewed before by Buekens & Schroyens (2003). Moreover, the positive correlation factor that is shown with the CO2 can be an impact from the correlation established earlier in Table 4.2.

Table 4.5: Spearman rho correlations between cleaning (frequency and material) and pollutant measurements ($p<0.05$)

Pollutants' Readings	Cleaning frequency	Cleaning material Type
Total VOC	-0.054	0.249**
CO_2 Mean	-0.144	0.281*
CO_2 Min	-0.123	0.260*
CO_2 Peak	-0.125	0.220*

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

The correlation between smoking in the indoor environment and the pollutants is shown in Table 4.6. The correlation factor is negative indicating that the readings of the CO2 increase, when no smoking is available. These results do not reflect the findings of the literature, for instance Simkhovich (2013), who confirmed that indoor environment pollutants increase with smoking. The researcher notes that none of the participating households' members were smoking at the time of the visit. Nonetheless, as a Libyan tradition, scented wood is lighted before a guest's visit. Several houses have performed this, which contributed into increasing the CO2 concentrations in the indoor environments of some of the participating households.

Table 4.6: Spearman rho correlations between pollutants' measurements and smoking in the house ($p<0.05$)

Pollutants' Readings	Allowing smoking in the house/ living room
CO_2 Mean	-0.147
CO_2 Min	-0.269*
CO_2 Peak	-0.231*

*. Correlation is significant at the 0.05 level (2-tailed)

Furthermore, weak to medium correlations were found between the number of residents in the household and the CO2 measurements, as shown in Table 4.7. The results indicate that the higher the number of the residents in the household, the higher the CO2 concentrations in the indoor air environment of the residential unit.

Table 4.7: Spearman rho correlations between pollutants' measurements and number of residents in the household ($p<0.05$)

Pollutants' Readings	Number of residents in the household
CO_2 Mean	0.190
CO_2 Min	0.275*
CO_2 Peak	0.311*

*. Correlation is significant at the 0.05 level (2-tailed)

Moreover, the data collected from the households are presented in Appendix 3.

5. CONCLUSIONS

As people spend the majority of their times in their house environments, any abnormalities in the indoor air quality could be harmful or fatal for the residential space occupants. Therefore, sustaining a healthy indoor air quality is essential for users' comfort and safety. Several factors could affect the indoor air quality; however, pollutants such as fine particles, VOCs, CO and CO_2, are considered within the most significant factors that lead to reducing it. In this research, the study aimed to study the correlation of certain habits of the occupants on the indoor air quality, along with architectural design factors, such as; cross-ventilation, finishing materials, and house orientation and openings.

The literature review showed that several studies have assessed the indoor air quality using either a questionnaire methodology, which helps understand the IAQ perception through a subjective assessment, or measurements of the indoor environment's pollutants as an objective methodology, or both. Thus, this research adds to the literature by considering both methodologies, along with architectural evaluations on cross-ventilation and finishing materials. The evidence is strong that pollutants in the indoor environment cause health and safety risks ranging between chronic issues, such as asthma, to allergies and irritations. The VOCs, Volatile Organic Compounds, form one of the most dangerous pollutants, as well as CO and CO_2, which could be fatal if exposed to in high concentrations. Therefore, it was important to consider these three pollutants in this study.

Increasing VOCs in the indoor environment can be a result of two main factors, which are the chemical agents used in cleaning and maintenance adhesives, and the brand-new furniture and casework. Moreover, habits such as cooking and smoking can increase the concentrations of CO and CO_2 significantly. Nonetheless, other factors such as indoor plantation and daily ventilation have proven to decrease the risk of the indoor environment pollutants.

The assessment was conducted through household visits to the Arab residents in Ankara. Twenty households agreed to participate in the study, where an architectural evaluation was conducted by the researcher for the interior design, measurements of the pollutants using two devices, one measuring total VOC and the other measuring the concentrations of CO and CO_2, was used to obtain objective measurements and a questionnaire that was taken by a member of the household. The results show that cross-ventilation is available in 35% of the participating households, where the others had two-sided or one-sided ventilations. A significant number of the households had no VOC's in their indoor environments, as well as no CO. However, the entire sample had certain extent of CO_2 content in their indoor environment, as a natural composite of the air. All of the participants have indicated a good to a very good perception of the IAQ in their houses, as well as different degrees of satisfaction.

In the correlational studies and discussion, strong to moderate correlations were found between the objective measurements. Moreover, cross ventilation had negative correlation with VOC readings, but positive correlations with CO and CO_2, which could be as a result of outdoor concentrations of those elements. Furthermore, cross-ventilation has showed a moderate influence on decreasing sickness frequency and allergies and increasing the IAQ satisfaction and its positive perception. Cooking and the type of ventilation used in the kitchen have also shown an influence on the studied pollutants, as well as the cleaning material used in the household. Factors like indoor plantations and smoking could not be proven to be correlated to the pollutants' measurements, due to lack of plantation and smoking activity at the time of the researcher's visits.

On testing the hypotheses designed for this study, the first hypothesis states "there is a correlation between the cross ventilation of the houses of the Arab residents in Ankara and the measured pollutants' level". Based on the results of the study shown in Table 4.2, cross-ventilation had weak to moderate correlation factors (at $p<0.05$). Therefore, the first hypothesis is accepted. The second hypothesis states "there is a correlation between the cleaning habits of the Arab residents in Ankara and the indoor air quality in their houses". The results in Table 4.5 show no correlation with the cleaning frequency of the household, Nonetheless, weak correlations were found with the type of cleaning material used, where chemical agents were correlated to higher levels of total VOC and CO_2. Therefore, the second hypothesis is accepted based on a significance level of $p<0.05$.

The third hypothesis states that "there is a correlation between the cooking habits of the Arab residents in Ankara and the indoor air quality in their houses". As shown in Table 4.4, both cleaning frequency and kitchen ventilation type had weak to moderate correlation factors with the three pollutants. Thus, the third hypothesis can be accepted considering a significance level of $p<0.05$.

The fourth hypothesis, which states that "there is a correlation between the presence of indoor plantation of the Arab residents in Ankara and the indoor air quality in their houses" could not be tested as none of the participating households have interior plantations.

Similarly, the fifth hypothesis states that, "there is a correlation between tobacco smoking habit of the Arab residents in Ankara and the indoor air quality in their houses". The results from Table 4.6 show weak negative correlation factors, which means that pollutants tend to increase in the space when its users do not smoke. Therefore, this can be explained that there are other causes for increasing the pollutants in the indoor environment, which affected this correlation. Although none of the participating households had tobacco smoking at the time of the researcher's visit, some household used scented wood burning before the researcher's visit. Based on that, this hypothesis cannot be accepted or rejected.

The sixth hypothesis states that "the Arab residents in Ankara have a satisfactory perceived indoor air quality in their houses". As shown in Figures 4.14, 45% of the participants indicated that they perceive their houses' IAQ as "good", while 55% perceive it as "very good". Moreover, the satisfaction results shown in Figure 4.15 show that 15% are slightly satisfied from their houses' IAQ, 60% are satisfied and 25% are very satisfied. Therefore, it can be concluded that the sixth hypothesis is accepted.

The seventh hypothesis states that "The level of IAQ is acceptable through pollutant measurement according to IAQ standards". As shown from the Total VOC, CO and CO_2 measurements performed in the participating households, and presented in the histograms in Figures 4.5, 4.6 and 4.7, the Total VOC mean reading was found as 145 ppb which is close to the acceptable limit of 120 ppb and away from the dangerous limit of 1,200 ppb. Moreover, the CO mean measurement was found as 0.7 ppm, which is less than the NAAQS standards limit of 9 ppm. The CO_2 mean was found as 965 ppm, which is below the ASHRAE standards limit of 970 ppm. Based on these results, the seventh hypothesis is accepted.

Furthermore, based on the results of the study and observations, the researcher would like to provide the following recommendations for residential unit users as guidelines to choose the healthiest house layout and finishing empowering a positive indoor air quality during the house selection:

1. Performing an IAQ investigation in new residential spaces in order to ensure safe levels of VOCs.
2. Carrying out intensive ventilation in case of performing maintenance activities, buying brand-new furniture and installing casework. According to the findings of the study, the availability of effective ventilation or cross-ventilation in the household has a weak correlation with lower pollutant concentrations and medium correlation with lower sickness levels.
3. Selecting a residential unit with a healthy cross-ventilation, as it is proven as a factor that influences IAQ. As proven by the results of this study, cross ventilation is found effective in decreasing the pollutants' concentrations in the indoor environment, as well as decreasing the risk of allergy occurrence and sickness frequencies.
4. Using soft cleaning agents that do not contain harsh chemicals such as Chlorine, acids and VOCs. The results of this research show that using chemical cleaning

agents is correlated to the increase of total VOC and CO_2 concentrations in the indoor environments of the residential units.

5. Despite of cooker hood availability, the kitchen shall be ventilated daily through opening windows. As presented in this study, the open window ventilation was correlated to decreased pollutant concentrations as shown in Table 4.4.

Several research opportunities can be carried out using the same methodology used in this research. Future research could support the findings of this thesis through covering a higher sample of households and including houses with lifestyle habits such as indoor plantation, pets, city locations and closeness to industrial areas. Moreover, different pollutants can be studied, including the essential pollutants included in this study, such as; sulfur and Particulate Matters (PMs), as these types of pollutants are found hazardous through the literature review and few studies have considered them in the residential environment. However, the current study could not implement these measurements due to the need of special measurement devices that were not available.

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APPENDIX 1

(MEASUREMENT SHEET)

Observations on architectural characteristics and measurements on VOC, CO, CO_2 in indoor living environments

<table>
<tr><td colspan="7">Part One: Architectural Assessment (by the researcher)</td></tr>
<tr><td>1</td><td>Cross ventilation</td><td colspan="2">No cross ventilation</td><td>1-sided</td><td>2-sided</td><td>Cross Ventilation</td></tr>
<tr><td>2</td><td rowspan="5">Finishing Material</td><td>Floor</td><td>Ceramic tiles
Wood
Marble</td><td colspan="3">Living room floor area
.... m^2</td></tr>
<tr><td>3</td><td>Wall</td><td colspan="4">Painted
Wallpaper
Tile</td></tr>
<tr><td>4</td><td>Ceiling</td><td colspan="4">Painted
Suspended tiles
Suspended gypsum
Wood</td></tr>
<tr><td>5</td><td>Window frame</td><td>Aluminum
Wood</td><td colspan="3">Living room window area
.... m^2</td></tr>
<tr><td>6</td><td>Door frame</td><td colspan="4">Iron
Aluminum
Wood</td></tr>
<tr><td>7</td><td>Total room number</td><td colspan="5">.......................................</td></tr>
<tr><td>8</td><td colspan="3">Have any maintenance activities been performed in the past 6 months? (Including painting, plastering, using adhesive material, and installing wooden material</td><td>YES</td><td>NO</td></tr>
<tr><td>9</td><td colspan="3">Have the household purchased any brand-new casework or furniture in the past 6 months?</td><td>YES</td><td>NO</td></tr>
<tr><td>10</td><td colspan="3">Is the house laying on a main road?</td><td>YES</td><td>NO</td></tr>
<tr><td>11</td><td colspan="3">House floor</td><td colspan="2">...........................</td></tr>
<tr><td rowspan="2">12</td><td rowspan="2">Facade sides (all applicable)</td><td>E</td><td>N</td><td>W</td><td>S</td></tr>
<tr><td>NE</td><td>NW</td><td>SE</td><td>SW</td></tr>
<tr><td colspan="7">Part Two: Pollutants' Measurement (By the researcher)</td></tr>
<tr><td>13</td><td colspan="3">Total VOC reading (ppm)</td><td colspan="2">......................</td></tr>
<tr><td rowspan="2">14</td><td rowspan="2">CO (ppm)</td><td>Mean</td><td>Min</td><td>Peak</td><td>Time</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">15</td><td rowspan="2">CO_2 (ppm)</td><td>Mean</td><td>Min</td><td>Peak</td><td>Time</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 2

(QUESTIONNAIRE FORM)

Survey on the Air Quality of Indoor Living Environments

Dear Sir/ Madam
We would like to take few minutes from your time to evaluate the indoor air quality and its problems in tour living environment. The quality of the indoor living environment can affect your health in the short and long run. Therefore, it is important to question and evaluate any issues the indoor air quality that your house, work or study place have.

All information and answers will be used only for the purpose of the study and will not be shared with any other person or institution.

Do you agree to take part in this research? YES NO

Part A: Demographics

1	Gender	Male	Female
2	Number of people living in the house	....	
3	Marital status	Single	married
4	Age Category	18 to 29	41 to 55
		30 to 40	Older than 55

Part B: Health Evaluation

5	How often do you get sick per year?	0 to 1	2 to 3	4 to 5	6 and more
6	Are there any chronic diseases within the family? (Cancer, Asthma, etc.)	YES		NO	
7	Do any of the family members suffer from skin irritations, eye, nose or ears infections or allergies, lung infections?	YES		NO	
8	Do any of the family members smoke?	YES		NO	

Part C: User's IAQ and Lifestyle Evaluation

9	How often food is cooked at your house?	Daily	3 to 4 times per week	4 times per month	Less than 4 times per month
10	What type of ventilation your kitchen has?	No ventilation	Small window	Exhaust fan	Cooker hood
12	How often do you clean your house?	Daily	3 to 4 times per week	4 times per month	Less than 4 times per month

<table>
<tr><th colspan="8">Part C: User’s IAQ and Lifestyle Evaluation</th></tr>
<tr><td>13</td><td>What cleaning material do you use for house?</td><td colspan="2">Water only</td><td colspan="2">Water & soap</td><td colspan="2">Agents (Domestos, Cif, etc)</td></tr>
<tr><td>14</td><td>Do you have any indoor plantation in your living room?</td><td colspan="3">YES</td><td colspan="3">NO</td></tr>
<tr><td>15</td><td>Do you smoke or allow smoking inside the living room?</td><td colspan="3">YES</td><td colspan="3">NO</td></tr>
<tr><th colspan="8">Part D: User’s IAQ Perception</th></tr>
<tr><td>16</td><td>How do you evaluate the indoor air quality in your house?</td><td>Very Good</td><td>Good</td><td>Slightly Good</td><td>Slightly Bad</td><td>Bad</td><td>Very Bad</td></tr>
<tr><td rowspan="3">17</td><td rowspan="3">Overall, how satisfied are you with the indoor air quality of your house?</td><td colspan="3">Very Satisfied</td><td colspan="3">Slightly unsatisfied</td></tr>
<tr><td colspan="3">Satisfied</td><td colspan="3">Unsatisfied</td></tr>
<tr><td colspan="3">Slightly Satisfied</td><td colspan="3">Very unsatisfied</td></tr>
<tr><td colspan="8">Thank you for your participation</td></tr>
</table>

APPENDIX 3

(DETAILED INFORMATION ON EACH SURVEYED HOUSE)

Household	Ventilation	Floor Finish	Living Room Area	Wall Finish	Ceiling Finish	Window Frame	Living Room Window Area	Door Material	Number of Rooms	Maintenance in the past 6 months?	New furniture in the past 6 months?	Near the main road?	Floor number	Total VOC ppm	CO Mean ppm	CO Min ppm	CO Peak ppm	CO_2 Mean ppm	CO_2 Min ppm	CO_2 Peak ppm
H1	CV	Wood	30,72	Paint	Paint	Alum.	1,8	Wood	3	No	No	No	2	0,1	1	2	2	1200	1600	1800
H2	CV	Wood	24,37	Paint	Paint	Alum.	1,44	Wood	3	No	No	No	2	0,1	0	0	0	800	900	1200
H3	2-Sided	Wood	32,46	Paint	Paint	Alum.	1,8	Wood	3	No	No	Yes	1	0,2	0	0	0	1200	1200	1400
H4	CV	Wood	30,72	Paint	Paint	Alum.	1,8	Wood	3	No	No	No	2	0,1	1	2	2	1200	1600	1800
H5	CV	Wood	20,88	Paint	Paint	Alum.	0,68	Wood	3	No	No	No	3	0	0	0	0	400	400	400
H6	2-Sided	Wood	32,46	Paint	Paint	Wood	1,62	Wood	3	No	No	Yes	2	0	0	0	0	500	500	600
H7	2-Sided	Wood	22,42	Paint	Paint	Alum.	1	Wood	3	No	No	No	2	0	0	0	0	500	500	500
H8	1-Sided	Wood	41,8	Paint	Paint	Wood	1,56	Wood	4	No	No	No	1	0	0	0	0	500	400	400
H9	2-Sided	Wood	30,71	Paint	Paint	Alum.	1,32	Wood	3	No	No	No	0	0	0	0	0	800	600	700
H10	CV	Wood	26,33	Paint	Paint	Alum.	2,71	Wood	3	No	No	Yes	0	0	0	0	0	500	600	600
H11	1-Sided	Wood	31,8	Paint	Paint	Alum.	1	Alum.	3	Yes	No	No	1	0,5	0	0	0	700	800	1000
H12	CV	Wood	30	Paint	Paint	Alum.	1,9	Wood	3	No	No	No	2	0,1	1	1	1	1000	1500	1700
H13	1-Sided	Wood	23,95	Paint	Paint	Alum.	1,35	Wood	3	No	Yes	No	3	0,2	0	0	0	1800	1600	1600
H14	1-Sided	Wood	18,5	Paint	Paint	Alum.	1,3	Wood	3	No	No	No	0	0,7	4	4	4	1200	1100	1100
H15	2-Sided	Wood	29,41	Paint	Paint	Wood	2,3	Wood	3	No	No	Yes	1	0,1	0	0	0	1300	1200	1300
H16	2-Sided	Wood	23,4	Paint	Wood	Wood	1,2	Wood	2	No	No	No	-1	0	0	0	0	700	500	600
H17	2-Sided	Wood	25,07	Paint	Paint	Alum.	1,6	Alum.	3	No	No	No	0	0,3	0	0	0	1000	800	1200
H18	CV	Wood	31,32	Paint	Paint	Alum.	2,84	Wood	2	No	No	Yes	2	0,3	3	3	3	1300	1400	1600
H19	2-Sided	Wood	19,21	Paint	Paint	Wood	0,9	Wood	3	No	No	No	0	0	0	0	0	700	600	1000
H20	2-Sided	Wood	25,8	Paint	Paint	Alum.	2,64	Wood	3	No	No	No	0	0,2	4	5	5	2000	2400	2600

CV = Cross Ventilation // Alum. = Aluminum