Indoor air quality assessment during lockdowns and improvement strategies for the residential houses in rural areas in Kazakhstan

(Master Thesis Progress)

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CHAPTER 1 - INTRODUCTION

1.1. Overview

It is well known that people spend most of their time indoors, hence Indoor Environmental Quality is vital and the first thing we need to put our focus on. The evaluation of indoor environment quality concerns both, how well the environment was built and the well-being of the building's occupants. The reason behind this concern is that majority of outdoor and indoor sources and equipment such as cooking and heating systems, can lead to poor IAQ and high concentrations of indoor pollutants.

WHO's global health observatory reports that in 2012, air pollution was the main cause of seven million deaths, while polluted air in houses and apartments showed 4.3 million deaths. This data represents approximately 7.7% of all people who die globally, had passed due to the issue of unclean air. Additionally, according to the US Environmental Protection Agency, indoor air pollution is the second most severe environmental danger to every human being's health. In WHO's previous research released in 2012 acute lower respiratory infections in children and heart problems caused by indoor air pollution are the leading causes of death.

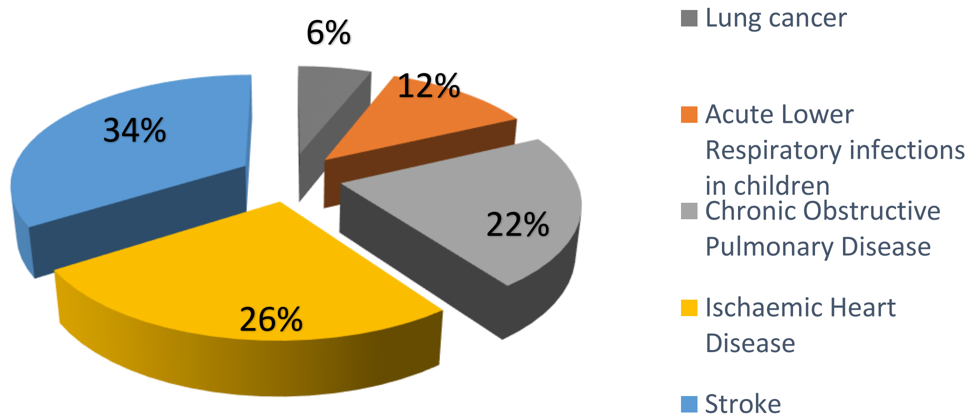


Figure 1. *Death rate percentages by diseases caused by indoor air pollution* (WHO, 2014)

1.2. Problem Statement

As human health and our environment continue to evolve, researchers have emerged as an essential focus for advancing our quality of life. Indoor air may be just as harmful as the outside air. That is to say that 90% of rural families in developing countries rely heavily on unprocessed biomass to meet their cooking needs, and around half of these households utilize poorly functioning cooking stoves (Wagdi 2015). Among the most dangerous substances emitted into the air by cooking equipment are CO2 (Carbon Dioxide), PM2.5 and PM10 particulate matter, and Formaldehyde. Moreover, women and young children, who are regularly exposed to a polluted atmosphere, suffer from health problems as a result of these inefficient cooking stoves and techniques.

This thesis project focuses on monitoring the indoor air quality of rural dwellings in Kazakhstan. Experiments in the project are conducted in houses and apartments where the cooking process is carried out through stoves indoors, typically in kitchens. Also, the cooking process was evaluated for I/O ratio behavior, and the home's ventilation systems were checked as well. Along with that, given that the infiltration rate of contaminants is affected by construction materials; the effect of primary structural materials is conferred. Furthermore, the effect of different building types on ventilation characteristics and air quality will be studied and looked at.

1.3. Research Objectives

Researchers tested their theories and hypotheses on seven dwellings in the countryside. In their research, building conditions, usage of materials, area of the investigation, and pilot study were assessed. It showcased that indoor PM2.5 can be related to outdoor levels however it is mostly affected by internal sources. Thus, both internal and external sources of PM2.5 were quantified, and their temporal dynamics and distributions were compared.

This master's thesis outlines the study questions, methods, findings, conclusions, and suggestions for future examination and investigation. The purpose of this study is to compare the indoor air quality of rural dwellings in Kazakhstan with that of metropolitan areas. For this particular reason, issues such as air pollution will be examined and debated to ensure it is appropriately managed. The next step in the study is identifying the most effective, acceptable, and cost-efficient control mechanisms and addressing the following aspects of the topic:

- Pollutant contamination rates are determined by air quality assessment monitoring, which includes carbon dioxide (CO2), Formaldehyde, and 2.5micron-sized particulate matter (PM2.5)
- Improved methods and technology for reducing dangerously high concentrations of indoor air pollution

The following research questions are suggested:

Q1: Do kitchen systems in rural regions emit air pollutants that are more detrimental to human health than those in metropolitan or urban areas?

Q2: Is it feasible to maintain the concentration of air pollutants at the same level to prevent respiratory diseases?

1.4. Research Method

1.4.1. Methodology Overview

The research plan consists of the following four goals:

1. Perform a literature review to discover the types of pollutants that impact human health and if yes, the treatment techniques for indoor pollutants.
2. International and local rules are examined to set standards. With those standards total of five monitoring places are used in rural area homes to monitor indoor air quality: the living room, the kitchen before cooking, the kitchen while it is cooking, and outside.

3. Determining if pollutants should be removed or treated. It is crucial to know as it is essential to an analysis of the data.
4. Lastly, in this part of the methodology overview, we will review contaminants that exceed international criteria for indoor air quality (IAQ) and examine the most efficient methods for eliminating them.

1.4.2. Study area and survey

The study area was chosen from the South Kazakhstan region. Precisely, villages that are located near the cities, Shymkent and Turkestan. The first village is 40 kilometers away from Shymkent, Mayatas, in particular, "Toleby Audany" is to be studied. The next area in the investigation is "Shornak" which is 30 kilometers from Turkistan. From those rural places' dwellings, living and kitchen rooms will be monitored for indoor air quality (IAQ). The kitchen and the backyard were utilized as the sensors' locations. As long as every home is unique, a questionnaire was created that included questions about the layout or the plan of the house, ventilation, smoking habits of dwellers, number of family members, and frequency with which windows were left open as a traditional ventilation method.

Besides, in the winter, as both communities rely on gas for warmth, a single inner door connects several dwelling rooms' kitchens and living areas. As a result, prominent families that live in cramped quarters are at risk for poor indoor air quality (IAQ). Table 1 shows the construction features of each of the seven residences, which helps explain how air contaminants enter homes.

Table 1. *Building characteristics*

House	Wall structure material	Insulation material	Kitchen room connection
1	Cob blocks	No	Direct connection with corridor
2	Burnt bricks	Styrofoam	Isolated by a wooden door
3	Burnt bricks	Styrofoam	Isolated by a wooden door

4	Cob blocks	No	Direct connection with living room
5	Cinder blocks	Styrofoam	Isolated by a wooden door
6	Cob blocks	No	Direct connection with outdoor door
7	Cob blocks	No	Isolated by a wooden door

Figures 2-8 depict the room layout and the locations of entrances and windows. Planning of rooms and placement of windows have an impact on interior airflow and ventilation.

Figure 2. *The layout of rooms, doors, and windows of house 1.*

Figure 3. *The layout of rooms, doors, and windows of house 2.*

Figure 4. *The layout of rooms, doors, and windows of house 3.*

Figure 5. *The layout of rooms, doors, and windows of house 4.*

Figure 6. *The layout of rooms, doors, and windows of house 5.*

Figure 7. *The layout of rooms, doors, and windows of house 6.*

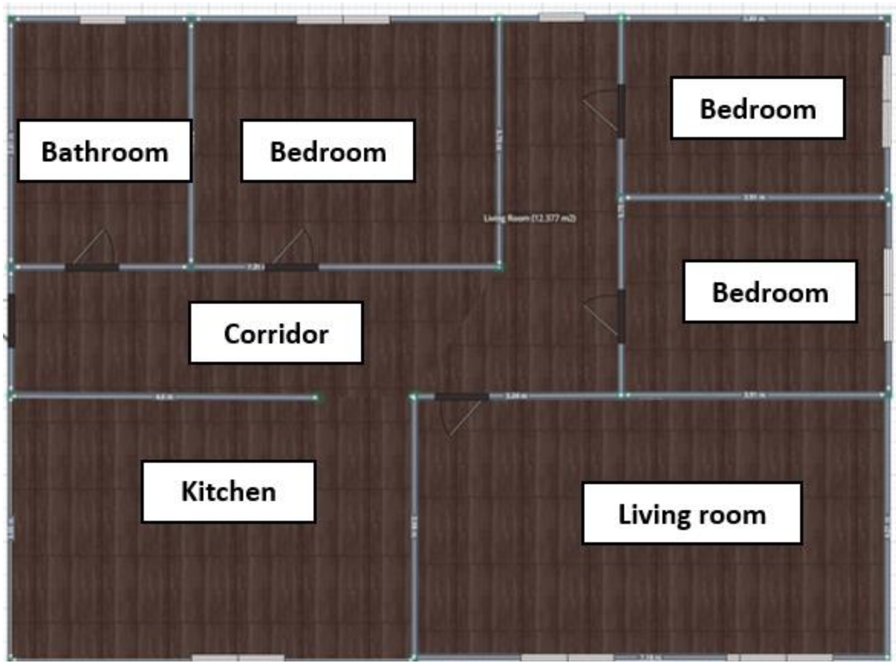


Figure 8. *The layout of rooms, doors, and windows of house 7.*

1.4.3. Material usage

Employed materials are a carbon dioxide meter, a thermal camera, and a Particulate Matter (PM) monitor. Figure 2 shows all three displays consumed for further measurements and studies. For precise and reliable data collection, all monitors were placed 2 meters away from fires and stoves, and 3 feet from the table.

Figure 9. *PM meter, CO_2 sensor, and thermal camera.*

For further data analysis, the carbon dioxide meter-monitor is ideal for precisely measuring CO_2 content in a contained space. The following factors; stability, precision, dependability, and decreased variability are the primary advantages of this equipment. And an indoor formaldehyde concentration monitor named "formaldehyde (CH2O) monitor" was developed specifically for this purpose.

1.4.4. Building recruitment

Homeowners were aware of the research area and the methods for monitoring their properties so it did not invade their privacy. This research examined seven residences in two villages in the Southern parts of Kazakhstan, Mayatas, and Shornak. The living rooms and kitchens were used for sampling and monitoring. The pilot test lasted for four hours in each residence.

1.5. Content and Organization

This chapter provides an overview of the research on indoor pollutants, their effects on human health, and the international regulations that have been set. Experiments and monitoring protocols are described in detail in Chapter 3 of this study. The fourth chapter discusses the results of the field studies utilizing the international standards compartment. In addition, this section focuses on the removal and control of indoor air contaminants. Chapter 5 concludes all the findings and provides recommendations. Ending references and appendices are provided for those who may find them useful.

Figures 10 and 11 represented the geolocation of Mayatas village according to Shymkent city and monitored houses 1-4.

Figure 10. *Geolocation of Mayatas village and Shymkent city.*

Figure 11. *Geolocation of monitored houses (1-4) in Mayatas village.*

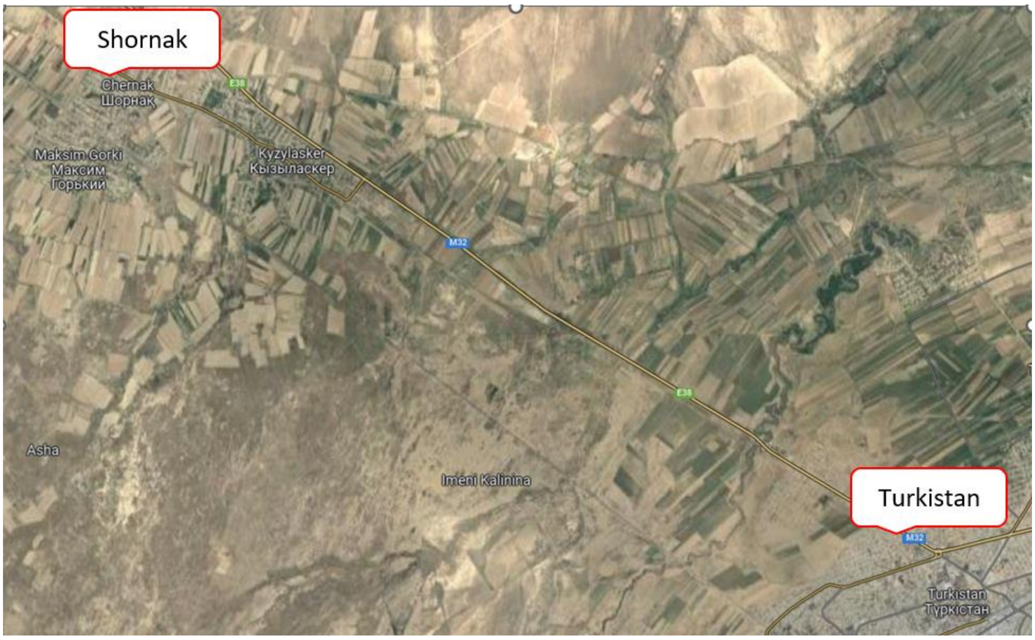


Figure 12. *Geolocation of Shornak village and Turkistan city.*

Figure 13. *Geolocation of monitored houses (5-7) in Shornak village.*

The geolocation of Shornak village is situated 30km from Turkistan city (Figure 12). The Shornak is a central village in the Turkistan region, as Turkistan city will become a central city of the South Kazakhstan region from 2021. Figure 13 illustrates the geolocation of monitored indoor air quality of houses 5-7.

CHAPTER 2 – LITERATURE REVIEW

2.1. Air Pollution

Air pollution is toxic substances in the atmosphere caused by various human activities such as motor vehicles, solid fuel combustion, industrial processes, and other factors depended upon humans. All these pollutants have different detrimental effects on the health of humans (Heimann 1961). These air pollutants are divided into two main categories:

- Primary pollutants are compounds discharged directly into the atmosphere from sources and are harmful at sufficient amounts, namely: Particulate Matter, Volatile organic, Nitrogen, Carbon, Halogen, and Sulfur compounds (Jamal et al. 2004).
- Secondary pollutants are not directly released from the exact sources; they are formed in the atmosphere because of chemical interactions between primary pollutants. Namely: NO_2, HNO_3, O_3, SO_2, NO_2, NH_3, and Organic aerosols (Sciences et al. 2009).

2.2. Air Quality in Kazakhstan

In Kazakhstan, which is considered as having harsh and cold winters, the energy supplies are ample. According to the data in 2015, 46% of the population resided in rural regions, yet only 25% of them had access to natural gas. However, 35% of dwellings in urban areas have direct heating systems installed, and 61% of those homes have access to a gas line to the distribution network (UNECE 2019). Another factor was the high urbanization rate, it helped to reduce the rural populations of Kazakhstan by 34% by 2020. Almost 80% of rural households utilize gas as a primary energy source according to the UNECE. The remaining of those rural villages in southern and central Kazakhstan are still heating their homes with coal.

The improved air quality in rural or suburban areas of Kazakhstan results from the increased accessibility of gas-powered central heating systems. In supplying gas to our country Uzbekistan plays a vital role, and it provides gas to the southern Kazakhstan areas of Zhambyl, Shymkent, and Kyzylorda. While west Kazakhstan's four provinces rely on Teniz's national gas product. Moreover, these native gas products are also consumed and utilized in Almaty and East Kazakhstan. Other north and central regions struggle the most with the availability of gas resources.

Another suggested way to reduce indoor pollution is to improve the efficiency of space heating systems (UNECE 2019). As according to the Organization for Economic Cooperation and Development, Kazakhstan's urban heat consumption per square meter is three times greater than in other European nations, so it seems that space heating systems have been inefficient. Particulate matter concentration levels in four major industrial cities in Kazakhstan have been shown in Figures 14 and 15 to be higher than WHO outdoor criteria. The statistics compare the concentrations of PM2.5 and PM10 with the daily maximums allowed.

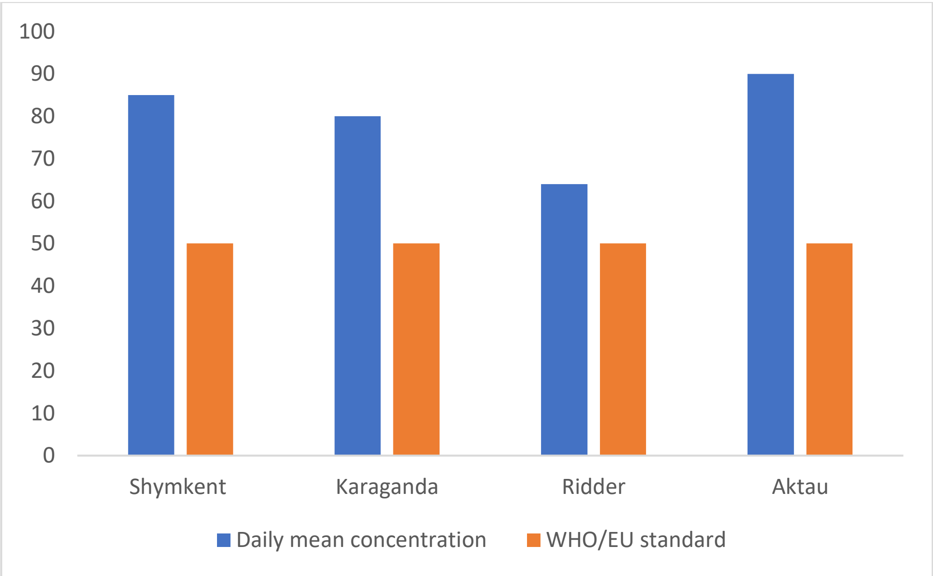


Figure 14. *The daily mean concentration of PM2.5 in selected cities in 2017 versus WHO/Eu standards of 50µg/m*^{3}

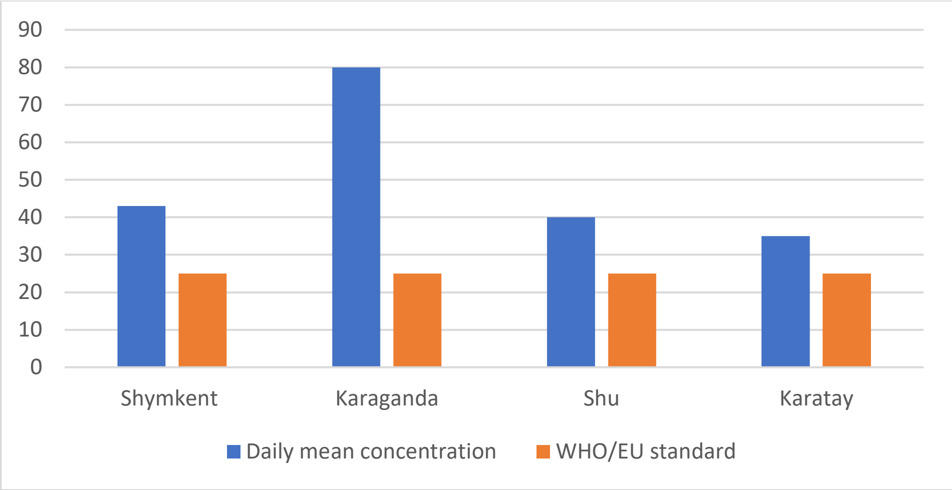


Figure 15. *The daily mean concentration of PM10 in selected cities, 2017 versus WHO/Eu standards of 25 µg/m*^{3}

According to official statistics, the total of adult deaths in Kazakhstan's core cities is 8252 yearly. More than half of all deaths were attributed to ischemic heart diseases, lower respiratory infection, stroke, and chronic pulmonary illness (Kerimray 2020). It is shown in Figure 16 that the mortality rate in Kazakhstan's key cities was affected by hazardous IAQ in 2018.

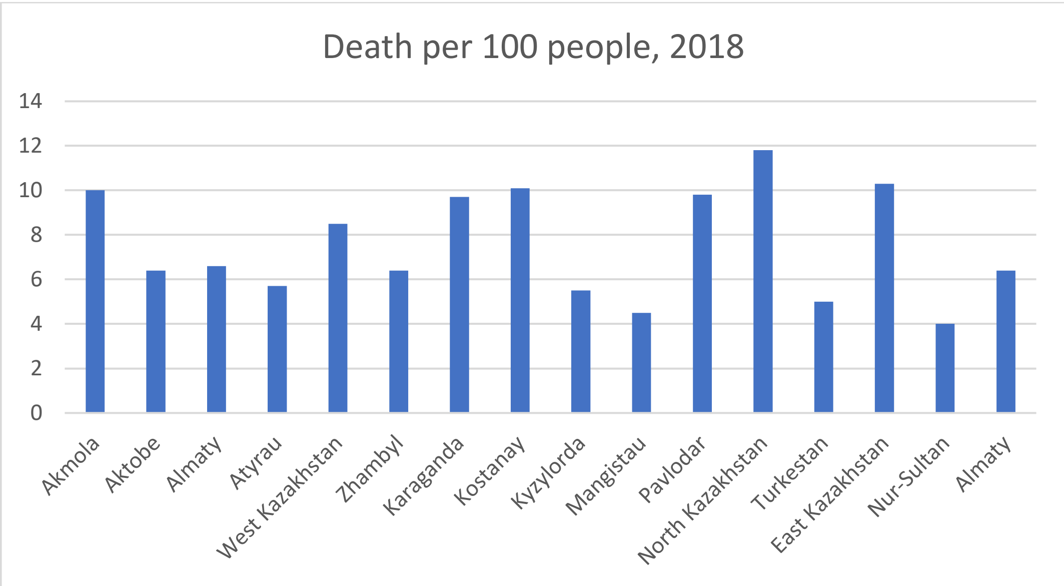


Figure 16. *Mortality rate per 100 adults in cities of Kazakhstan*

2.3. Indoor Air pollutants

The air pollutants, as with the case of air quality, can also be categorized as either outdoor or interior. The most common outdoor air pollutants are motor vehicle emissions, solid fuel burning, and industrial pollution. Contaminants found in homes and flats are "indoor air pollutants" (Slezakova 2012). Because people spend so much time inside at work and home, the importance of good indoor air quality cannot be overstated (Jacobson 2012). The World Health Organization (WHO) estimates that 2.7 percent of people worldwide are killed by poor indoor air quality. There is a minor increase in the mortality rate in emerging nations, which stands at 3.7% of the total population (Health 2008). The following is a list of the three principal pollutants that influence indoor air quality.

- Cooking, personal hygiene, and smoking habits are all examples of personal activities
- Cleaning supplies and deodorizers are examples of household cleaning supplies.
- Remodeling the property with new materials, furnishings, and other routine maintenance duties (Tebbe 2017).

Interactions with doors and windows also impact indoor air quality (IAQ). Soil gas pollutants, such as those from automobiles and factories, and emissions from other nearby sources, can impact interior air quality.

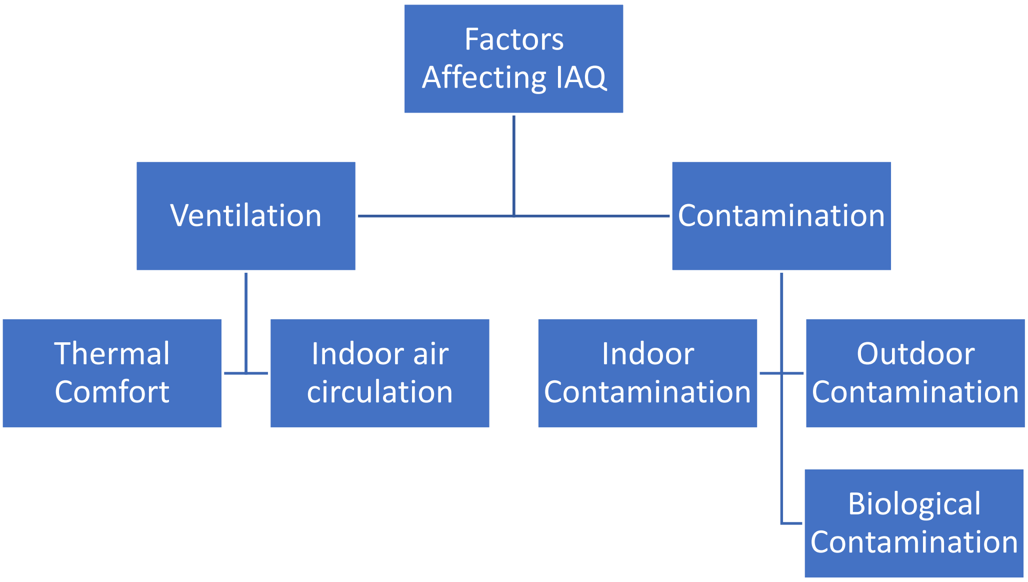


Figure 17. *Factors affecting IAQ.*

Figure 17 depicts the two factors that impact Indoor Air Quality (IAQ): pollution and ventilation. Indoor air circulation, thermal comfort, and outside air supply via fresh air are the three primary determinants of ventilation. Temperature, humidity, and airflow all affect thermal comfort in different ways. A further source of indoor pollution is toxins from the outside, which enter or are transferred into inside rooms through open doors and windows. Also, contaminated by interior activities like cooking, smoking, home renovations, HVAC systems, and even structural material emits some pollution. The number of people living in residence significantly impacts the amount of CO2 emitted (Crincinelli and Martellini 2017).

IAQ has a significant impact on human well-being and comfort. There are three basic types of indoor air pollutants: particulate matter, organic and inorganic pollutants. Many organic contaminants may be found in a home or workplace, including viruses, pollen, fungus, and bacteria (Wagdi 2015). PM2.5 and PM10 are the most often studied pollutants in research and tests (Crincinelli and Martellini, 2017).

2.3.1. Total Volatile Organic Compounds and effects on wellbeing

Total Volatile Organic Compounds (TVOC) is the abbreviation for this term. A gas at room temperature is made of organic compounds. There are tens of thousands of different types of VOCs. Benzene, ethylene, toluene, Formaldehyde, tetrachloroethylene, and methylene chloride are only a few primary examples of volatile organic compounds (VOCs). Outdoor and indoor sources of TVOC include cleansers, disinfectants, plywood, carpets, and furniture. TVOC (Crincinelli and Martellini 2017). Table 3 shows the concentration guidelines for TVOCs and the level of concern.

Table 3. *TVOC standards with the relation of level of concern to human health.*

TVOC Level	**Level of Concern**
Less than 0.3 mg/m^3	Low
0.3 – 0.5 mg/m^3	Acceptable
0.5 – 1.0 mg/m^3	Marginal
1.0 – 3.0 mg/m^3	High

The level of danger posed by TVOC is determined by factors such as the duration and intensity of exposure. In addition, youngsters have a greater capacity for empathy than the elderly. As a result of the behavior of younger people, TVOC contaminant abuse can cause symptoms including dizziness and headaches (Anderson 1997). T Eye and respiratory system irritations were the first signs of illness. Television overuse sickness (TVOC) is known to cause nausea, dizziness, and exhaustion in its victims. Additionally, even at low concentrations, toluene can induce allergic skin irritation. When VOCs are inhaled at high levels over an extended period, they can damage renal and nervous system function (Anderson 1997).

2.3.2. Formaldehyde and effects on wellbeing

The carbonyl contaminant family includes Formaldehyde (HCHO), a volatile organic pollutant. Wood products are the principal source of formaldehyde pollution in indoor air. Furniture and structural components from wood may also be found in parquet and laminate floors (Crincinelli and Martellini 2017). Wagdi claims that Formaldehyde's discomfort causes central nervous system issues and its first symptoms include irritation of the throat, eyes, and nose, followed by allergic reactions and other adverse effects. Long-term exposure to high levels of Formaldehyde can cause exhaustion, coughing, and wheezing. Indoor formaldehyde concentrations are inversely correlated with temperature and humidity (Tang 2009).

2.3.3. Carbon Dioxide and effects on wellbeing

Carbon dioxide (CO2) is a pollutant that can easily be measured since living organisms release it. A low concentration of CO2 in the indoor environment might produce headaches and sleepiness in building inhabitants. Particulate matter per meter cube (PM10) concentrations of carbon dioxide typically range between 350 and 400 in the open air. The WHO recommends a maximum indoor CO2 concentration of no more than 1000 parts per million (ppm) for human health (Persily 2015). Humans are the primary cause of this pollutant in most buildings as the exhaled air is the way that carbon dioxide is emitted. The CO_2 level should be lowered to 600 ppm, closer to the outdoor level, to reduce the risk of health issues. Otherwise, ventilation systems should be installed indoors if the concentration level exceeds the set limits and norms. There is a slew of health risks associated with prolonged CO_2 exposure. Various symptoms can accompany dizziness and vertigo, such as a pins-and-needle sensation in the hands and feet, a rapid heartbeat and blood pressure, suffocation, convulsions, and weariness (Robertson 2006).

2.3.4. Particulate Matter and effects on wellbeing

It is possible to distinguish particulate matter (PM) by size and chemical or biological structure. Particles that are in the air can be measured as having less than 10 microns. Biological and non-biological contaminants make up most of what airborne particulate matter consists of. Particulate matter (PM) may smoothly pass through the respiratory system of humans, and the smaller the particle that got in, the greater the risk to human health. What is more, most of the indoor air pollutants are affixed to particulate matter (PM) and transferred to the body via the human immune system. PM's danger level might significantly vary depending on several factors; namely, emission source, concentration, and presence of other indoor pollutants. Therefore, to avoid complications or diseases to human health, concentrations should range from 250 to 350 g/m^3, which is considered safe for human health (Wagdi 2015). It is now well accepted that inhaling particulate particles poses health at high risk, so the long-term and short-term effects of PM on human health are examined.

In the examination, in contrast to long-term exposure, short-term (hours to days) exposure to radiation is unlikely to have any noticeable adverse health effects on humans (months – years). Another indicators of high concentrations of particulate matter in the air for extended periods of time are respiratory failure, asthma, and cancer of the lungs, according to Sacks, 2011 was a direct outcome of long-term exposure to PM.

2.4. Control of Indoor Air Quality

Reduction of indoor pollutant concentrations might be accomplished through these three ways: source management, ventilation, and air cleansing. When any building is in need of fresh air, then it is necessary for it to have ventilation. A building's improper ventilation systems influence the buildup of polluted air within that building. Thence, a well-thought-out ventilation system may help in keeping building's occupants satisfied and healthy. In order for the building to be properly ventilated, the interior space, the airflow direction, ventilation rate, and dispersion are all critical (Air and Munksgard 2004). The ventilation rate in the previous sentence is the calculated amount of fresh air that is outside the selected indoor area. For instance, to properly ventilate the cooking area, exhaust fans should be installed close to the stove. As Crincinelli and Martellini, 2017 suggested, a healthy home environment is made possible by a well-functioning ventilation system.

The problem of indoor air pollution may also be reduced by using the source control approach. This method regulates and eliminates the buildup of impurities and the sources of emissions (Wang 2004). For that, outdoor smoking areas should be established as it is the best method of curbing people's habitual smoking. Additionally, using an air filter or purification system helps in removing particulate matter, dust, and other contaminants from the air in the workplace. Along with air filters the measurement of air velocity, temperature, and humidity helps to understand the interior air quality. In addition to that, proper direction of airflow is essential to maintain a healthy interior environment and a high indoor air quality level (Board 2016).

CHAPTER 3 – Results and Analysis

As it was mentioned in the previous parts of this work, high accumulation of harmful indoor pollutants is emitted during the cooking process. The concentration of air pollutants directly depends on the kitchen room's structure and layout, and ventilation system. According to the collected questionnaire, all of chosen seven houses do not use stove hooks during the cooking process. This research concentrated on rural area IAQ; therefore, the house owners make use of the traditional ways of the ventilation system. Opening windows and doors correctly allows the fresh outdoor air to enter and replace accumulated indoor air pollutants. They use that method 4-5 times in summer and up to 2 times in winter seasons per day. However, some house owners stated that this method is implemented twice or three times a week which is below the normal air ventilation. The main reason for that behavior among those families is the fear of catching cold for children, who have lower resistance to cold and not as immune to many illnesses as adults. Some other factors were the financial constraints that affected the living style in rural areas. Due to that people used to economize on communal electricity, gas, and water sources. That habit has impacted the indoor air quality, as on the way of economizing on the heating system.

3.1. Application of IAQ Benchmark

The IAQ benchmark was constructed to evaluate and discuss the monitored data with international standards. This framework allows us to compare the allowability of indoor air pollutants for human well-being. The benchmark consists of three primary levels, represented in Figure 18.

Level 1	• The kitchen room charecteristics
Level 2	• IAQ Benchmark
Level 3	• Cooking details

Figure 18. *The framework of the IAQ benchmark assessment*

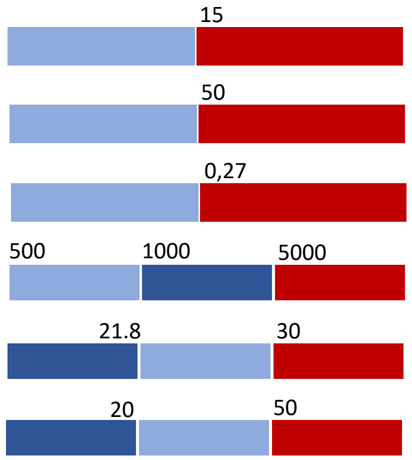
The framework depicts the IAQ benchmark based on house structural features and culinary specifics. The volume of the kitchen room and building materials are noted in the first stage - the structural components of wall structure, floor finishing, wall finishing, and door and window materials. Furthermore, family members and smoking habits were noted. The second level includes data on five air pollutants' concentrations and an IAQ benchmark based on WHO 2017 criteria. The last step provides more detailed information on each household's cooking method, including the cooking duration, consumed stove plates simultaneously, ingredients, and meal type.

Phase 1: The kitchen room characteristics

House - 1	Kitchen
Area **Volume**	m^2 m3
Materials	Wall Structure (WS.) Floor Finishing (FF.) Wall Finishing (WF.) Door material Window material
Family members	Adult or child
Smoking behavior	

Phase 2: Construction of IAQ Benchmark:

Before cooking (15:00-16:00)

<table>
<tr><th>Parameter</th><th>Average hour readings</th><th>Benchmark</th></tr>
<tr><td>1. PM 2.5
2. PM 10
3. HCHO
4. CO_2
5. Temperature
6. Humidity</td><td>ug/m^3
ug/m^3
mg/m^3
ppm
Celsius
%</td><td>
</td></tr>
<tr><td>Acceptable IAQ</td><td></td><td></td></tr>
<tr><td>Needs Improvement</td><td></td><td></td></tr>
<tr><td>Unacceptable</td><td></td><td></td></tr>
</table>

Cooking details	
Duration	The total duration of each used gas stove plates
Meal type	Meal type and cooking style
Weight of Ingredients	Meat
	Oil
	Vegetables
	Groat
	Water

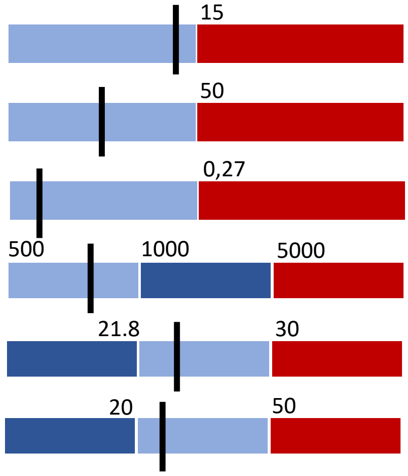
The concentrations of air contaminants in each cooking stage were measured using one-hour average data. PM2.5, PM10, CO2, HCOH, temperature, and humidity levels were generated and compared to WHO standards. The literature study searched for similar publications on IAQ in schools, hospitals, and offices. The majority of the research compares IAQ to ASHRAE and WHO criteria. The standards are categorized by WHO organization criteria for what is acceptable for human well-being. Table 4 shows the maximum allowable pollutants concentration for a one-hour exposure.

Table 4. *The maximum allowable IAQ concentration for human wellbeing (WHO 2017)*

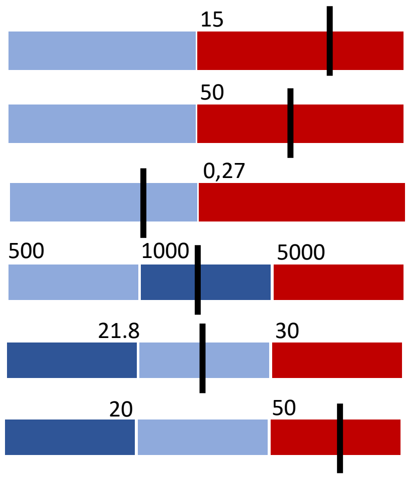
Pollutants	Allowable	Needs Improvement	Unacceptable
PM2.5	>15 ppb	-	Over 15 ppb
PM10	>50 ppb	-	Over 50 ppb
CO_2	>1000 ppm	1000 – 5000 ppm	Over 5000 ppm
HCOH	>0.27 mg/m^3	-	Over 0.27 mg/m^3
Humidity	20-50%	-	50-100%
Temperature (Heating seasons)	21.8 – 30 Celsius	-	Below 21.8 Celcius Higher 30 Celcius

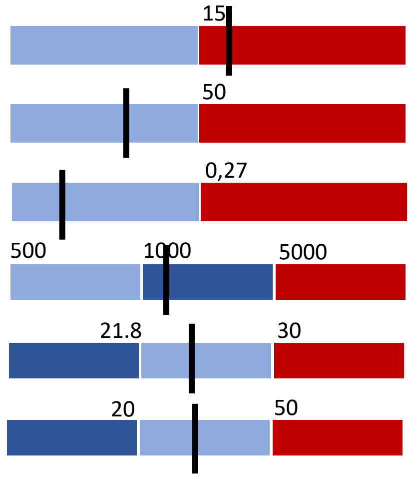
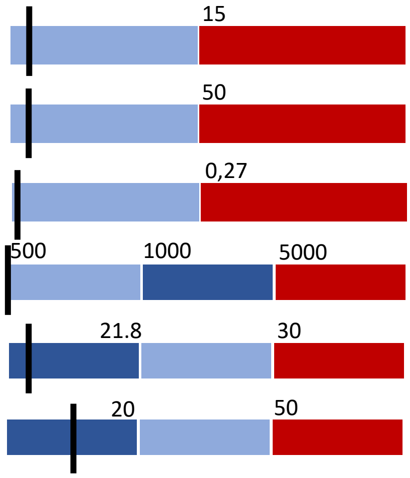
House - 1	Kitchen
Area **Volume**	8.75 m^2 21.875 m3
Materials	W.S.:cob blocks FF: ceramic tiles WF: wallpaper Door: wood Window: plastic
Family members	2adult, 4child
Smoking behavior	No

Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
7. PM 2.5	14.5 ug/m^3	
8. PM 10	24.6 ug/m^3	
9. HCHO	0.05 mg/m^3	
10. CO_2	851 ppm	
11. Temperature	23.5 Celsius	
12. Humidity	25.8%	



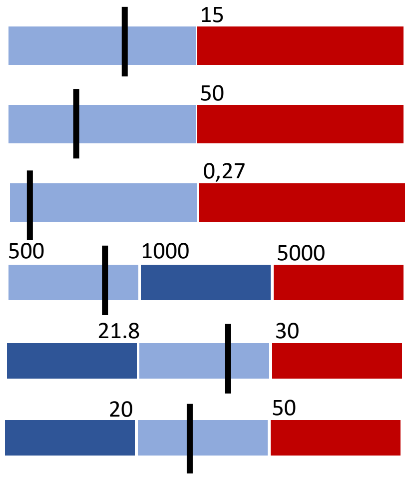
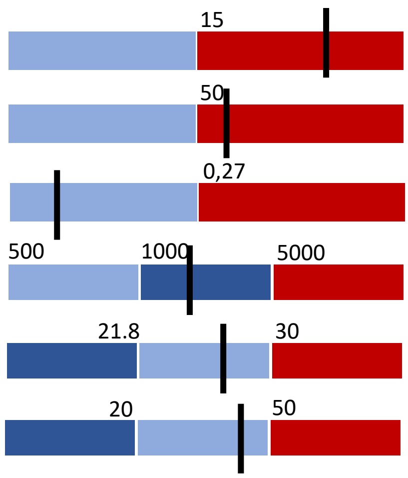
In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
1. PM 2.5	48.31 ug/m^3	
2. PM 10	85.28 ug/m^3	
3. HCHO	0.19 mg/m^3	
4. CO_2	3932 ppm	
5. Temperature	25.64Celsius	
6. Humidity	73.86%	

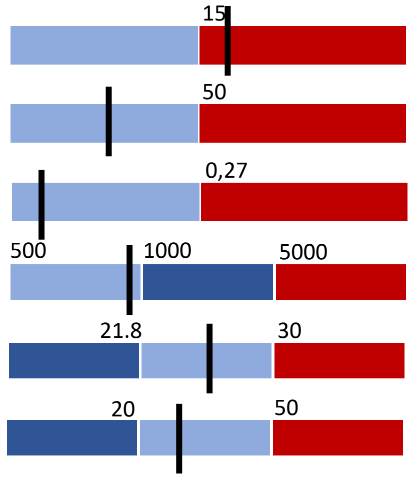
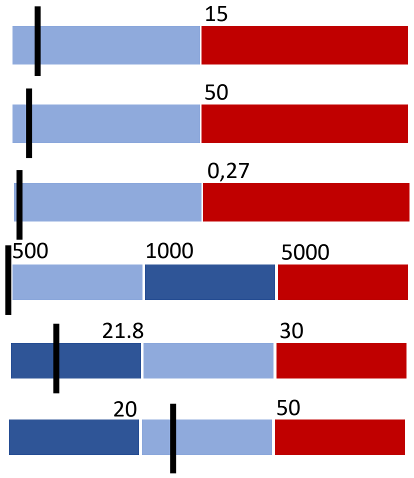


After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
1. PM 2.5	17.3 ug/m^3	
2. PM 10	32.8 ug/m^3	
3. HCHO	0.07 mg/m^3	
4. CO_2	1151 ppm	
5. Temperature	24.2 Celsius	
6. Humidity	30.8%	
Outdoor air quality		
Parameter	Average hour	Benchmark
1. PM 2.5	3.7 ug/m^3	
2. PM 10	6.2 ug/m^3	
3. HCHO	0.01 mg/m^3	
4. CO_2	425 ppm	
5. Temperature	5.7 Celsius	
6. Humidity	11.8 %	

Cooking details		
Duration	Three gas stove plates, 1-47 min, 2-22 min, 3-12 min	
Meal type	The first meal prepared at the cauldron	
Ingredients	Meat	321 grams
	Oil	150 ml
	Vegetables	Onion-2pieces, Potata-4pices
	Groat	Rice – 400 gram
	Water	300 ml

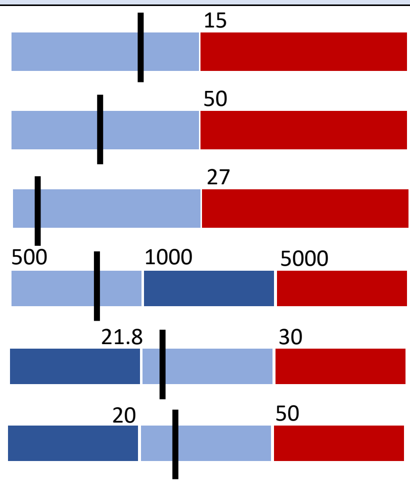
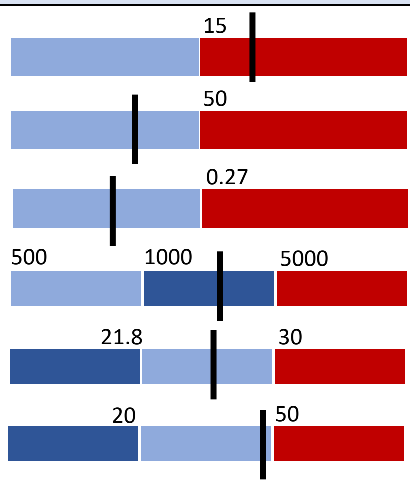
House - 2	Kitchen
Area **Volume**	9 m^2 24.3 m3
Materials	WS: burnt brick FF: linoleum WF: Paint Door: wood Window: plastic
Family members	One adult, five child
Smoking behavior	No

Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
13. PM 2.5	11.7 ug/m^3	
14. PM 10	18.7 ug/m^3	
15. HCHO	0.03 mg/m^3	
16. CO_2	826 ppm	
17. Temperature	26.1 Celsius	
18. Humidity	29.5 %	
In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
7. PM 2.5	32.02 ug/m^3	
8. PM 10	56.3 ug/m^3	
9. HCHO	0.07 mg/m^3	
10. CO_2	2156 ppm	
11. Temperature	26.7 Celsius	
12. Humidity	43.8 %	

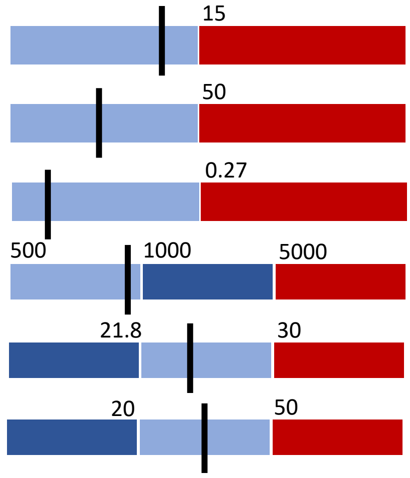
After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
7. PM 2.5	15.7 ug/m^3	
8. PM 10	25.2 ug/m^3	
9. HCHO	0.05 mg/m^3	
10. CO_2	978 ppm	
11. Temperature	25.7 Celsius	
12. Humidity	27.3 %	
Outdoor air quality		
Parameter	Average hour	Benchmark
7. PM 2.5	3.3 ug/m^3	
8. PM 10	5.76 ug/m^3	
9. HCHO	0.01 mg/m^3	
10. CO_2	412 ppm	
11. Temperature	8.4 Celsius	
12. Humidity	27.5 %	

Cooking details		
Duration	Gas stove consumed for 40min	
Meal type	Soup is prepared in a cauldron by boiling the water	
Ingredients	Meat	232 grams
	Oil	30-50 ml
	Vegetables	Onion-1pieces, Potata-2pices
	Groat	Noodles– 400 gram
	Water	1500 ml

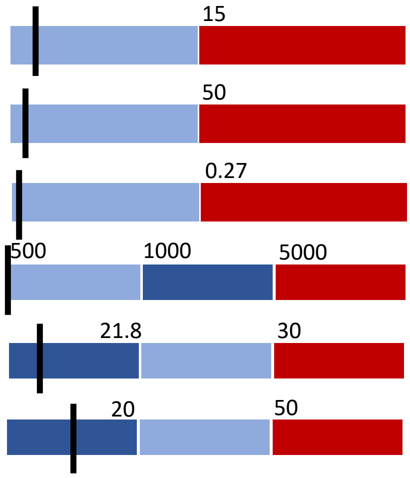
House - 3	Kitchen	
Area **Volume**	12 m^2 36 m3	
Materials	WS: burnt brick FF: linoleum WF: paint Door: wood Window: plastic	
Family members	2adult, 2child	
Smoking behavior	No	

Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
19. PM 2.5 20. PM 10 21. HCHO 22. CO_2 23. Temperature 24. Humidity	12.7 ug/m^3 22.5 ug/m^3 0.04 mg/m^3 783 ppm 22.3 Celsius 28.5%	
In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
13. PM 2.5 14. PM 10 15. HCHO 16. CO_2 17. Temperature 18. Humidity	18.24 ug/m^3 30.64 ug/m^3 0.11 mg/m^3 2484 ppm 26.6 Celsius 49.81%	

After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
13. PM 2.5	14.1 ug/m^3	
14. PM 10	23 ug/m^3	
15. HCHO	0.06 mg/m^3	
16. CO_2	982 ppm	
17. Temperature	25.5 Celsius	
18. Humidity	32.4 %	

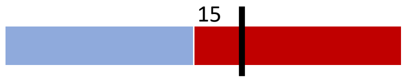
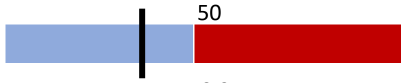
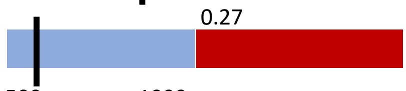
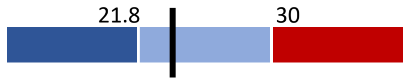
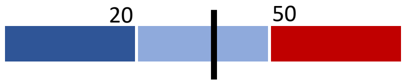
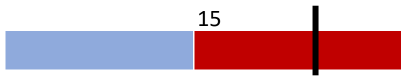
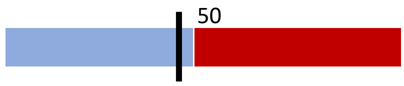
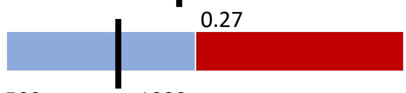
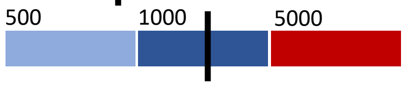
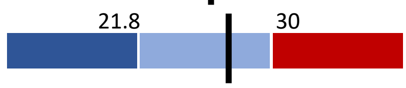


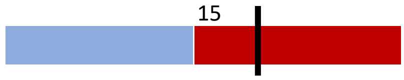
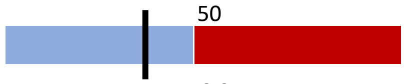
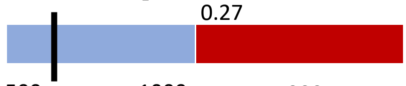
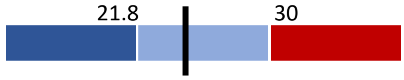
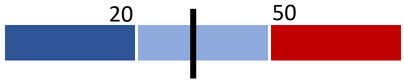
Outdoor air quality		
Parameter	Average hour	Benchmark
13. PM 2.5	4.2 ug/m^3	
14. PM 10	7.8 ug/m^3	
15. HCHO	0.01 mg/m^3	
16. CO_2	453 ppm	
17. Temperature	7.3 Celsius	
18. Humidity	11.1 %	

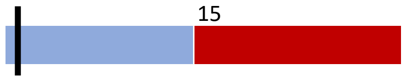
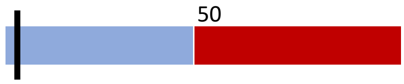
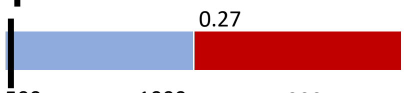


Cooking details		
Duration	gas stove - 48 min	
Meal type	First meal prepared at the cauldron, zharkoe fired by oil	
Ingredients	Meat	344 grams
	Oil	50-80 ml
	Vegetables	Onion-2pieces, Potata-1kg, Carrot-1piece
	Groat	No
	Water	300 ml

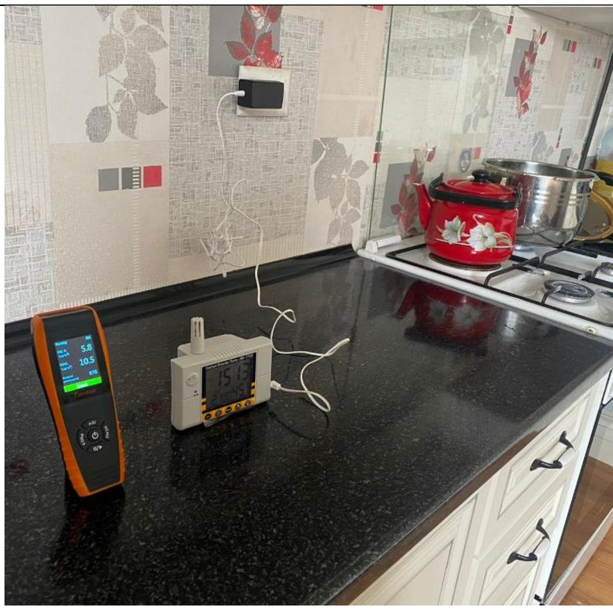
House - 4	Kitchen	
Area **Volume**	18 m^2 48,6 m3	
Materials	W.S.:cob blocks FF: wood WF: wallpaper Door: wood Window:2-plastic	
Family members	Four adults, two child	
Smoking behavior	No	

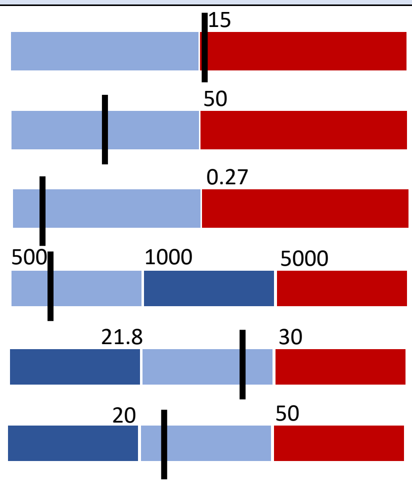
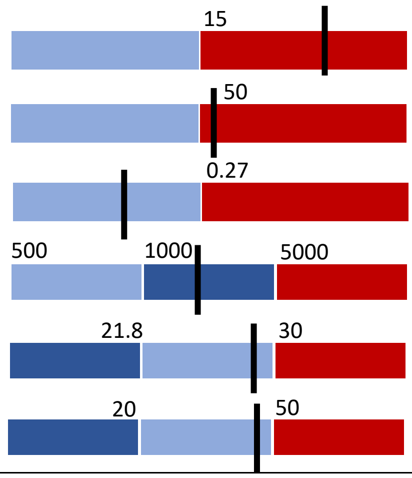
Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
25. PM 2.5	17.8 ug/m^3	
26. PM 10	35.4 ug/m^3	
27. HCHO	0.05 mg/m^3	
28. CO_2	942 ppm	
29. Temperature	25.8 Celsius	
30. Humidity	37.4 %	
In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
19. PM 2.5	27.23 ug/m^3	
20. PM 10	48.72 ug/m^3	
21. HCHO	0.15 mg/m^3	
22. CO_2	2550 ppm	
23. Temperature	26.6 Celsius	
24. Humidity	49.3 %	

After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
19. PM 2.5	20.3 ug/m^3	
20. PM 10	37.3 ug/m^3	
21. HCHO	0.07 mg/m^3	
22. CO_2	1078 ppm	
23. Temperature	24.3 Celsius	
24. Humidity	29.8%	

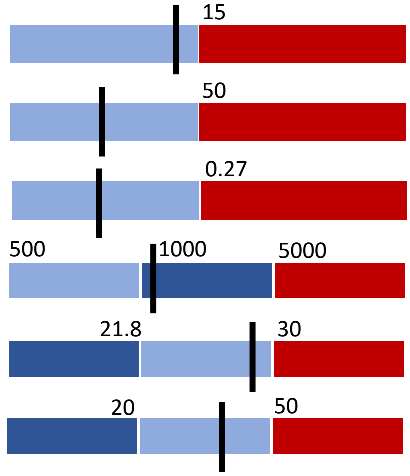
Outdoor air quality		
Parameter	Average hour	Benchmark
19. PM 2.5	3.8 ug/m^3	
20. PM 10	7.5 ug/m^3	
21. HCHO	0.01 mg/m^3	
22. CO_2	447 ppm	
23. Temperature	7.1 Celsius	
24. Humidity	14.2 %	

Cooking details		
Duration	gas stove 60 min + Tefal (7min)	
Meal type	First meal prepared at cauldron (Plov), closed cap	
Ingredients	Meat	327 grams
	Oil	150 ml
	Vegetables	Onion-2pieces, Carrot 700-800gm
	Groat	Rice – 500 gram
	Water	600 ml

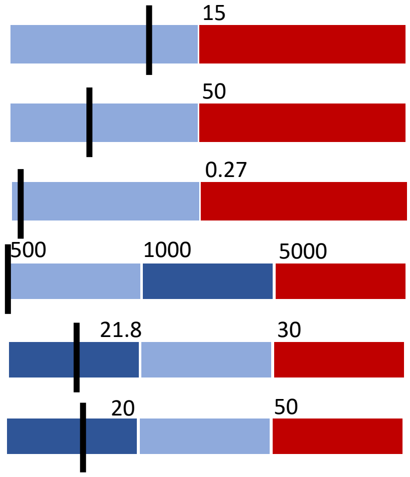
House - 5	Kitchen	
Area **Volume**	15 m^2 45 m3	
Materials	WS: cinder blocks FF: parquet WF: wallpaper Door: wood Window: plastic	
Family members	Two adults, three child	
Smoking behavior	No	

Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
31. PM 2.5	15.3 ug/m^3	
32. PM 10	25.9 ug/m^3	
33. HCHO	0.05 mg/m^3	
34. CO_2	694 ppm	
35. Temperature	27.7 Celsius	
36. Humidity	24.7 %	
In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
25. PM 2.5	30.27 ug/m^3	
26. PM 10	50.86 ug/m^3	
27. HCHO	0.17 mg/m^3	
28. CO_2	2483 ppm	
29. Temperature	29.3 Celsius	
30. Humidity	48.17 %	

After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
25. PM 2.5	14.1 ug/m^3	
26. PM 10	24.0 ug/m^3	
27. HCHO	0.11 mg/m^3	
28. CO_2	1087 ppm	
29. Temperature	28.1 Celsius	
30. Humidity	30.1 %	



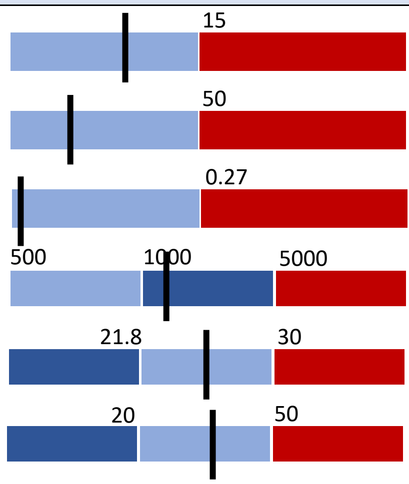
Outdoor air quality		
Parameter	Average hour	Benchmark
25. PM 2.5	12.8 ug/m^3	
26. PM 10	22.3 ug/m^3	
27. HCHO	0.01 mg/m^3	
28. CO_2	422 ppm	
29. Temperature	12.4 Celsius	
30. Humidity	12.0 %	



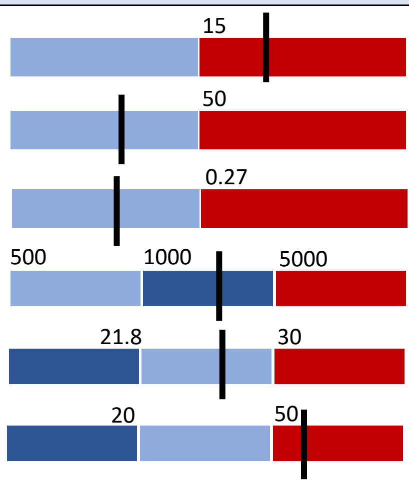
Cooking details		
Duration	Two gas stove plates, 0-42min (42min), 27-60min (33min)	
Meal type	Soup is prepared in a cauldron by boiling the water	
Ingredients	Meat	176 grams
	Oil	150 ml
	Vegetables	Onion-1piece, Potata-2pices Cabbage – 500 gm
	Groat	No
	Water	1750 ml

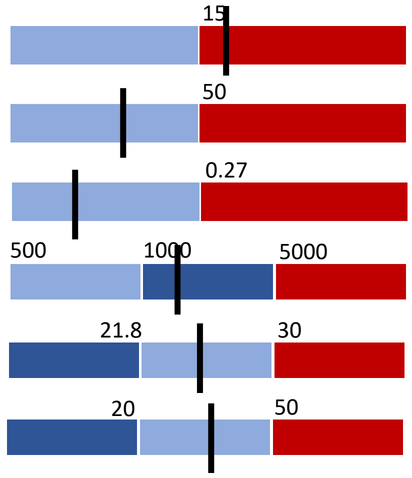
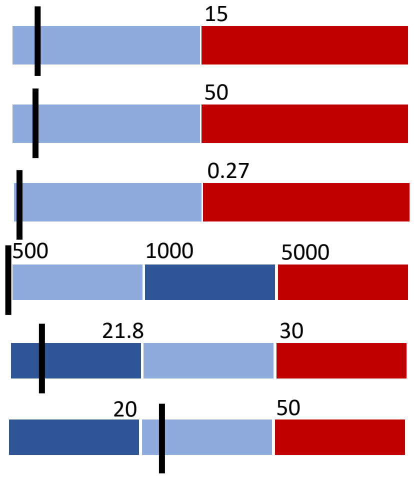
House - 6	Kitchen
Area **Volume**	10 m^2 28 m3
Materials	WS: cob blocks FF: wood tiles WF: paint Door: wood Window: plastic
Family members	2adult, 3child
Smoking behavior	Yes, one adult

Before cooking (15:00-16:00)		
Parameter	Average hour	Benchmark
37. PM 2.5	11.1 ug/m^3	
38. PM 10	16. ug/m^3	
39. HCHO	0.02 mg/m^3	
40. CO_2	1148 ppm	
41. Temperature	25.2 Celsius	
42. Humidity	34.3 %	

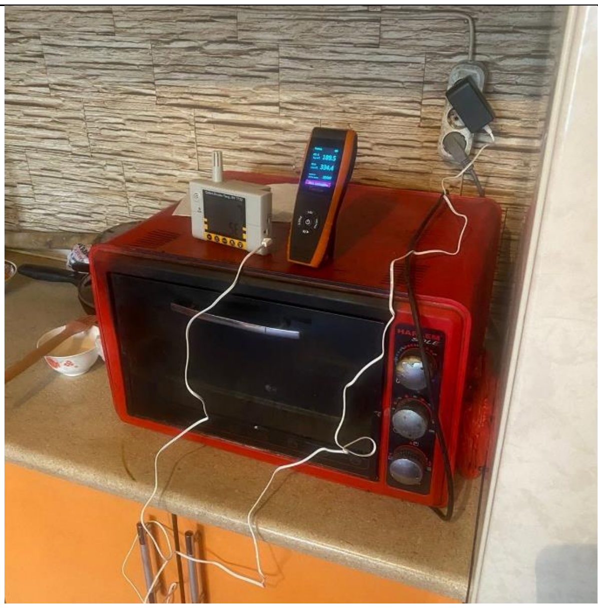


In the cooking process (17:27-18:27)		
Parameter	Average hour	Benchmark
31. PM 2.5	18.0 ug/m^3	
32. PM 10	30.9 ug/m^3	
33. HCHO	0.15 mg/m^3	
34. CO_2	2786 ppm	
35. Temperature	26.7 Celsius	
36. Humidity	56.02 %	



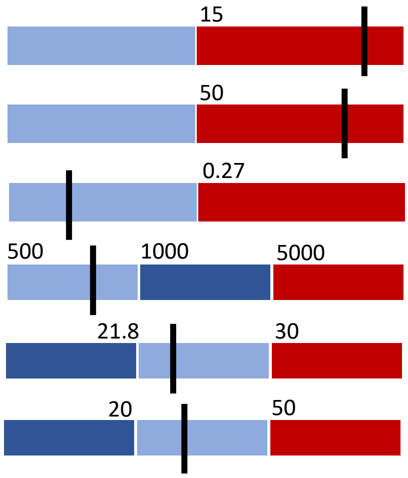
After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
31. PM 2.5 32. PM 10 33. HCHO 34. CO_2 35. Temperature 36. Humidity	16.1 ug/m^3 27.6 ug/m^3 0.09 mg/m^3 1351 ppm 25.8 Celsius 34.5 %	
Outdoor air quality		
Parameter	Average hour	Benchmark
31. PM 2.5 32. PM 10 33. HCHO 34. CO_2 35. Temperature 36. Humidity	6.8 ug/m^3 11.3 ug/m^3 0.01 mg/m^3 417 ppm 5.7 Celsius 22.8%	
Cooking details		
Duration	Gas stove plates 54 min	
Meal type	First meal prepared at cauldron by firing in the oil	
Ingredients	Meat	251 grams
	Oil	80-100 ml
	Vegetables	Onion-2pieces, Potata-5pieces
	Groat	Dough – around (800-1000gramm)
	Water	750 ml

House - 7	Kitchen
Area **Volume**	6 m^2 15 m3
Materials	WS: cob blocks FF: linoleum WF: wallpaper Door: wood Window: plastic
Family members	Three adults, two child
Smoking behavior	No



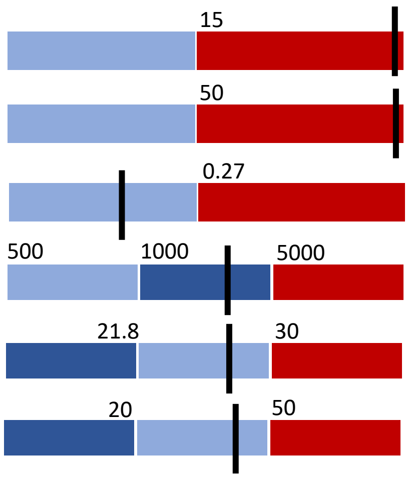
Before cooking (15:00-16:00)

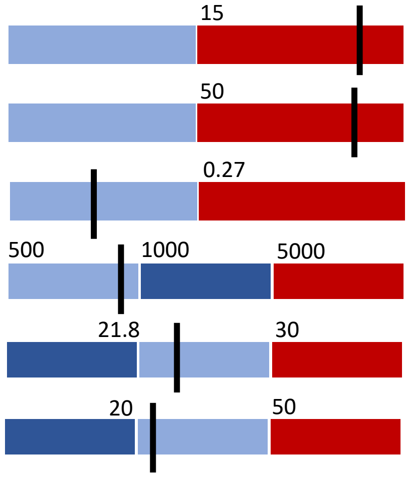
Parameter	Average hour	Benchmark
43. PM 2.5	85.7 ug/m^3	
44. PM 10	156.2 ug/m^3	
45. HCHO	0.08 mg/m^3	
46. CO_2	743 ppm	
47. Temperature	22.3 Celsius	
48. Humidity	27.7 %	

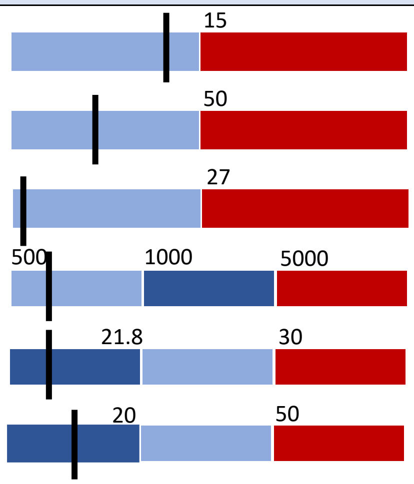


In the cooking process (17:27-18:27)

Parameter	Average hour	Benchmark
37. PM 2.5	266 ug/m^3	
38. PM 10	436.1 ug/m^3	
39. HCHO	0.15 mg/m^3	
40. CO_2	3080 ppm	
41. Temperature	26.72 Celsius	
42. Humidity	43.95 %	



After the cooking process (19:00-20:00)		
Parameter	Average hour	Benchmark
37. PM 2.5	138.2 ug/m^3	
38. PM 10	233.7 ug/m^3	
39. HCHO	0.09 mg/m^3	
40. CO_2	943 ppm	
41. Temperature	23.8Celsius	
42. Humidity	22.9%	

Outdoor air quality		
Parameter	Average hour	Benchmark
37. PM 2.5	14.1 ug/m^3	
38. PM 10	22.8 ug/m^3	
39. HCHO	0.03 mg/m^3	
40. CO_2	651 ppm	
41. Temperature	8.1 Celsius	
42. Humidity	12.3 %	

Cooking details		
Duration	Three gas stove plates, 1-24 min, 2-35min + Tefal (8min)	
Meal type	1)first meal heated(cauldron), egg+potato fired in the oil	
Ingredients	Meat	No data
	Oil	100 ml
	Vegetables	Potata- 3pices, (eggs – 5 pieces)
	Groat	No data
	Water	No

3.2. Relationship between indoor and outdoor air pollutants

The I/O index measures the ratio of indoor and outdoor concentrations. It is an essential measurement of the relationship between interior and outside air quality - the higher the value, the less influence outdoor air quality has on IAQ. The air exchange ratio is heavily influenced by housing structure and construction materials. Table 5 summarizes the CO2, PM2.5, and PM10 I/O air relationships. The green indicates the lowest I/O ratio, while the red indicates the most outstanding results. Before the cooking activity, the I/O value for PM2.5 ranged from 1.20 to 6.08; 1.16 to 6.85 for PM10; and 1.14 to 2.11 for CO2. The cooking process substantially increased as the ratio of all three contaminants threefolded. As a result, the I/O ratio of pollutants reduced gradually one hour after the cooking activity.

Table 5. *The I/O ratio value of air pollutants*

	Kitchen (cooking)	House-1	House-2	House-3	House-4	House-5	House-6	House-7
PM2.5	Before	4,14	3,55	3,02	4,68	1,20	1,63	6,08
	At	13,06	9,70	4,34	7,17	2,37	2,65	18,87
	After	4,68	4,76	3,36	5,34	1,10	2,37	9,80
PM10	Before	3,97	3,25	2,88	4,72	1,16	1,49	6,85
	At	13,75	9,78	3,93	6,50	2,28	2,73	19,13
	After	5,29	4,38	2,95	4,97	1,08	2,44	10,25
CO2	Before	2,00	2,00	1,73	2,11	1,64	2,27	1,14
	At	9,22	5,23	5,48	5,70	5,88	6,68	4,73
	After	2,71	2,37	2,17	2,41	2,58	3,24	1,45

House-7 illustrates the highest ratio for all three examining pollutants. WHO 2017 standards do not accept the I/O relationship and must vary from 1.6 to 2.6. The main reason for the high ratio is that the building structure is completely shielded from the sun and wind. Comparingly, the I/O value in House 5 has the lowest value for PM2.5 and PM10. However, the carbon dioxide concentration rocketed, resulting in a 5.88 I/O ratio because of the ingredients and unusual cooking. Figures 19, 20, and 21 show the concentrations of PM2.5, PM10, and CO_2 in the kitchen room as a function of cooking activity.

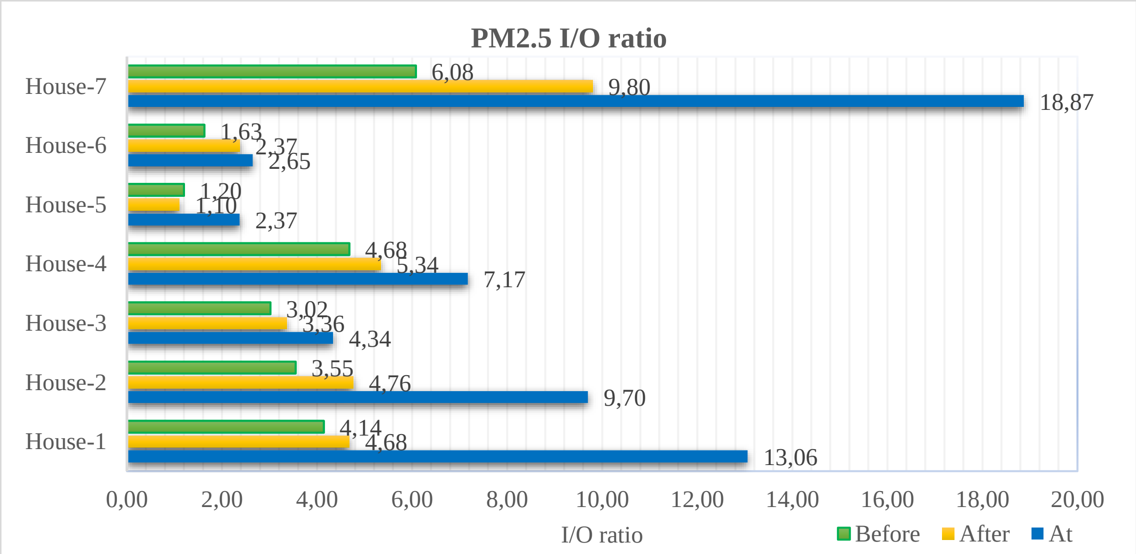


Figure 19. *PM2.5 I/O index in the kitchen room (before/during/after cooking)*

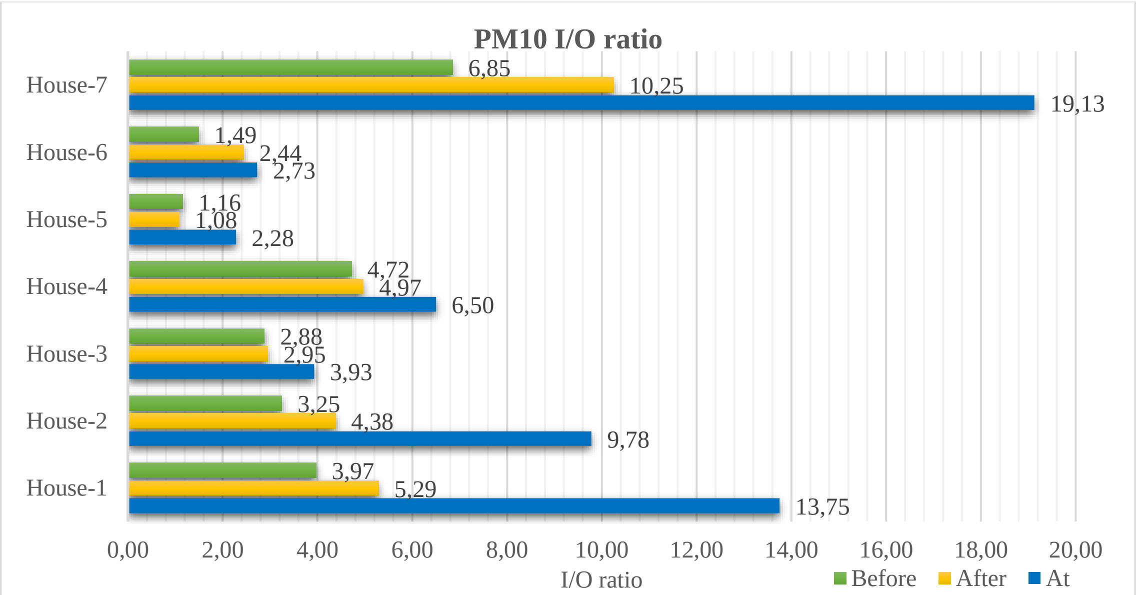


Figure 20. *PM10 I/O index in the kitchen room (before/during/after cooking)*

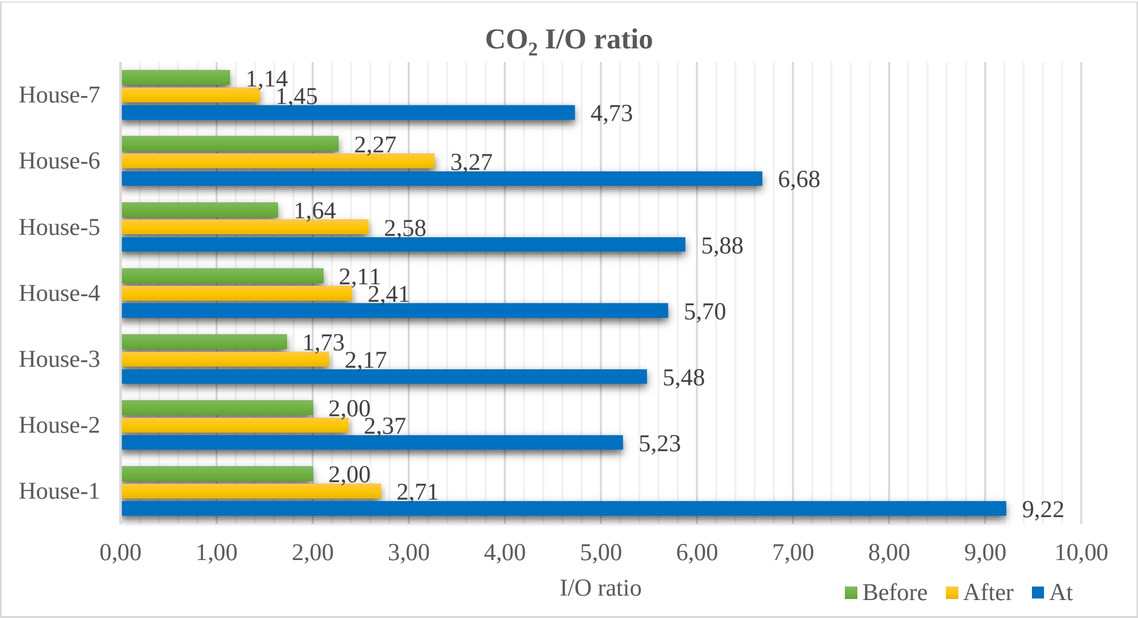


Figure 21. *CO_2 I/O index in the kitchen room (before/during/after cooking)*

The I/O ratio is 2-3 times higher during cooking than before and after the cooking process. Precisely one hour after the cooking, the pollutants' behavior differs in all seven houses; according to family members living styles, high pollutants deposition in small-volume cooking rooms. As a result, the traditional ventilation system is used immediately after cooking by opening windows and doors. None of the dwellings employ stove hoods as ventilation to reduce dangerous pollutants emitted by cooking activity. House-7 Saving vegetables in a box corresponds to a high level of particulate matter accumulation in the kitchen.

3.3. Carbon Dioxide behavior at cooking time

Figure 22 illustrates the CO2 progress rate during cooking in the kitchen room. The y-axis indicates CO2 concentration in ppm, and the x-axis shows 2min time steps.

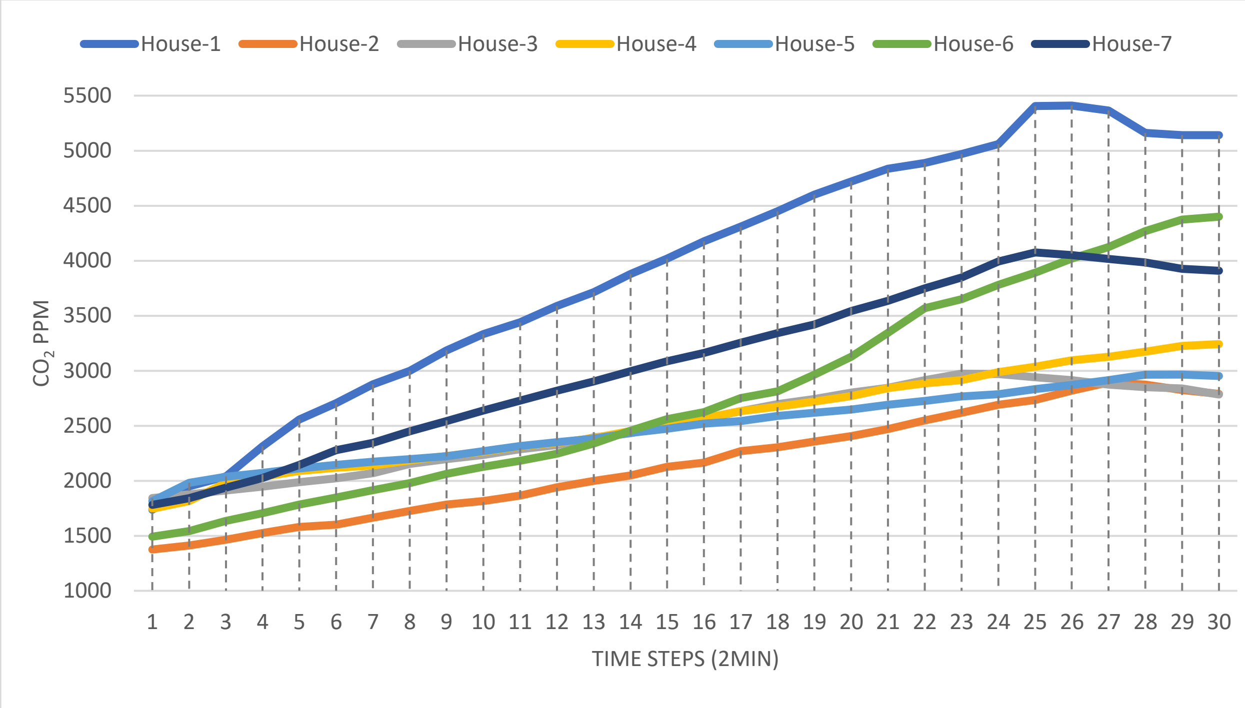


Figure 22. *CO_2 trend in the cooking process*

The carbon dioxide emission rate during the cooking process is affected by room volume, cooking duration, ingredients, utilized gas stove plates, etc. Table 6 shows the key parameters affecting on carbon dioxide emission rate.

Table 6. *CO_2 emission rate following various parameters.*

House №	**1**	**2**	**3**	**4**	**5**	**6**	**7**
CO_2 trend %	604	350.36	379.82	344.16	425.36	371.78	548.45
Meal type	Main Course	Soup	Main course	Main course	Main course	Soup	Main course
Kitchen area (m^2)	8.75	9	12	18	15	10	6
Kitchen volume (m^3)	21.875	24.3	36	48.6	45	28	15
People in kitchen	3	2	2	3	2	2	2
Duration	47	40	48	60	54	60	35
2nd Stove duration	22	-	-	-	33	-	24
3rd Stove duration	12	-	-	-	-	-	-
Tefal	-	-	-	7	-	-	8

Cooking style	Firing in oil	Boiling the water	Firing in oil	Firing in oil	Firing in oil	Boiling the water	Heating and firing
Meat (gram)	321	232	344	327	176	251	-
Oil	150	30-50	50-80	150	150	80-100	100
Water	300	1500	300	600	1750	750	-
Condition of cap	Open	Closed	Closed	Closed	Open	Closed	Open

The above-illustrated graph indicates the same trend line for all monitoring houses. The progress rate is mainly impacted by the kitchen's space volume, cooking technique, and used gas stove plates simultaneously. Main meals that are prepared in these kitchen rooms, particularly in the cauldron, are done so by firing the oil mixed with meats and vegetables, whereas soup is prepared by merely boiling the ingredients in the water. Meals which are cooked by the firing method demonstrate a higher carbon dioxide emission rate. The lowest progress rate was detected in houses 2 and 6, as soup preparation emits significantly lower CO2 concentration. In addition, the final progress rate reached 350.36% for house 2, and room volume (24.3m3) and duration of the used stove (40 mins) played a significant role. However, house 6 has the more volumetric kitchen room, but the duration of the cooking lasted for an hour. That impacted in the higher progress rate of carbon dioxide of 371.78%. The bigger the volume of the kitchen room, the lower the accumulation rate of pollutants. Therefore, house 4 had the highest room volume among seven houses and obtained the lowest progress rate of CO_2.

Houses 1,5 and 7 consumed two and more gas stove plates simultaneously during the cooking process, which led to a more than 400% progress rate. House 1 showed a record progress rate of 604%, consuming three gas stove plates. The minor volumetric kitchen (15 m3) resulted in the second highest increase rate of 548.45%. Overall, the carbon dioxide accumulation rate strongly depended on room volume, cooking style, duration, and used gas stove plates simultaneously.

3.4. Thermal Comfort and Heating systems

The final study was conducted in the winter when a house uses its heating system which then impacts indoor air quality. The average outside temperature ranged from 3.4 – 9.5 Celsius, whereas the average indoor temperature ranged from 23.4 to 31.4 Celcius. Rural area house owners live in economically poor conditions, so heating systems are usually switched off to overcome extra waste for better financing.

The traditional ventilation system aids in improving IAQ conditions in the house, as wind enters from one window and leaves by taking harmful contaminants from the opposite window site. However, this method is not applied frequently in the winter, as little children might get sick quickly by cold temperatures. Further, this air ventilation method will lead to a dramatic decrease in the house's temperature level, which is not beneficial from a financial perspective as people spend money trying to heat the house. That action of saving money correlates with the high accumulation of PM2.5, PM10, and CO_2 pollutants compared to the pilot study measurements. Figure 23 illustrates thermal pictures of the heating system, and the average temperature of the gas heat machines is about 52-54 Celsius.

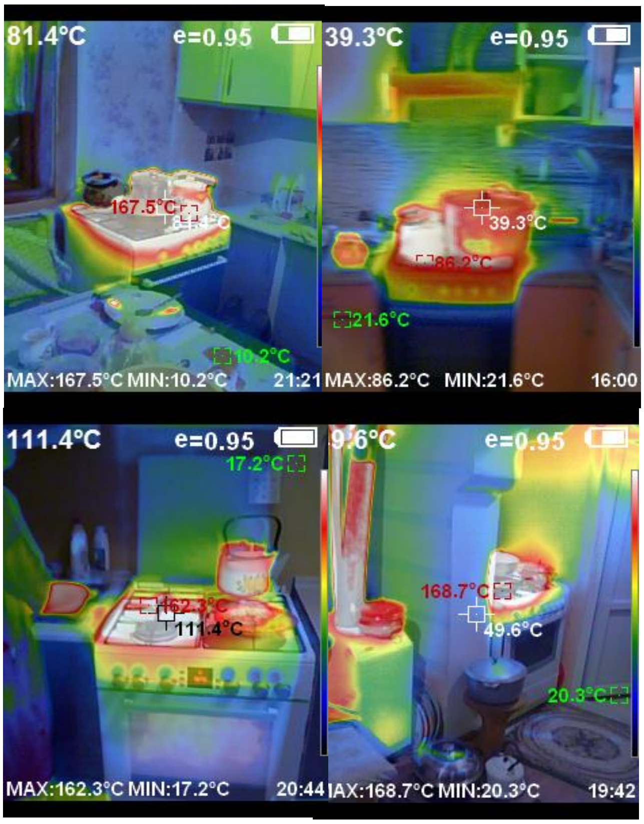


Figure 23. *Thermal photos of heating systems*

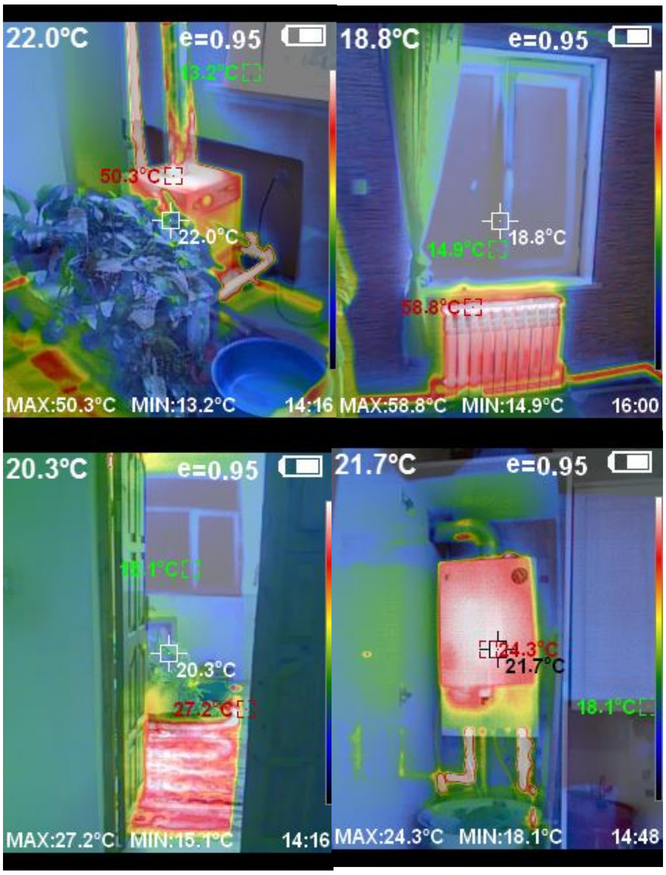


Figure 24. *Thermal photos of the cooking process at the stove.*

Figure 24 shows the thermal photo of the stoves during the cooking time. In the process of cooking, gas stoves heat to 150 Celsius. The dramatic temperature rise leads to increasement in the humidity level and CO_2 in the kitchen.

3.5. Effect of heating system on CO_2 concentration indoors

The pilot and final studies were carried out on the identical seven houses' kitchen rooms. The pilot measurements lasted only 20 mins in October when heating systems were switched off. However, according to ASHRAE and WHO regulations, the minimum time duration of investigation should exceed one hour of exposure. After considering this recommendation, the indoor air quality results can be judged according to the maximum allowable concentration for human wellbeing under which the exposure is not harmful to people.

The investigation was conducted when the heating systems were switched off. The outdoor temperature level varied from 13-19 degrees in celsius. The second monitoring was conducted in January when the outdoor temperature ranged from -3 to 9 Celsius. At this investigation stage, house owners made use of a gas heating system to raise the indoor temperature. So, the table that is shown below illustrates the CO_2 level in ppm for both of the studies in the kitchen room. Moreover, the differences between the two monitoring investigations are shown in percentage, and graphical representation plotted in Figure 25.

Table 7. *Carbon Dioxide (ppm) level in the kitchen room for both studies.*

	House-1	House-2	House-3	House-4	House-5	House-6	House-7
Pilot Study (CO_2 ppm)	694,4	576,8	783	821	583,6	1350,7	711,1
Final Study (CO_2 ppm)	851	826	889,7	942	694	1148	743
Difference in %	22,5%	43,20%	11,99%	14,74%	18,92%	-15,01%	4,49%

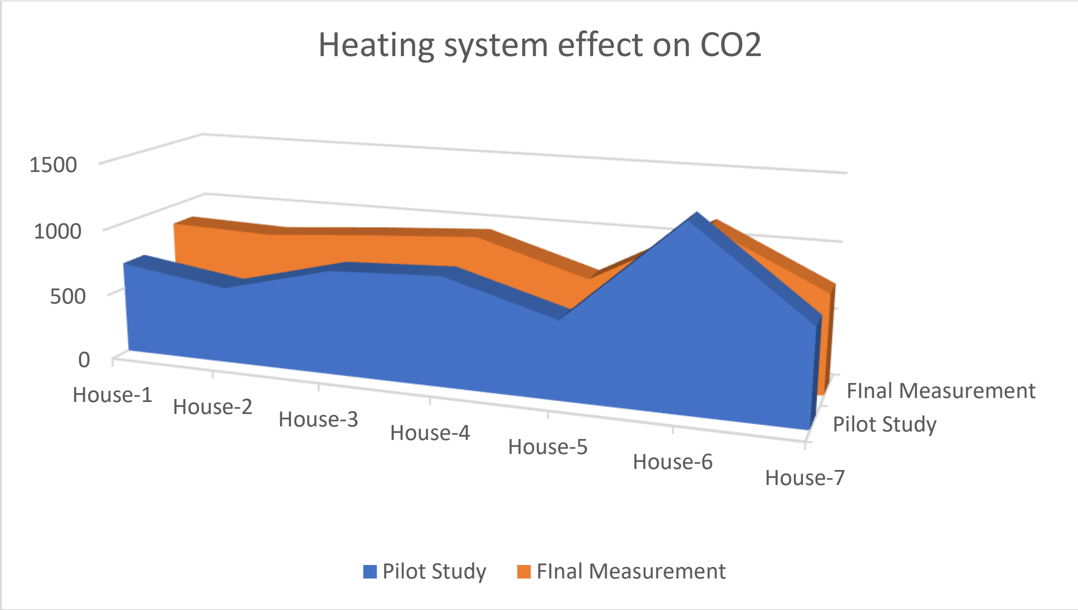


Figure 25. *Thermal photos of the cooking process at the stove.*

The aboveshown graph illustrates the comparison of CO_2 concentration of two monitorings that were conducted on seven identical houses in southern parts of Kazakstan. The pilot study was measured in October, and the final measurement was recorded in January and February. The main difference between the two studies is the outdoor temperature level that led to the usage of heating systems inside the houses. According to the graph, the CO_2 emission level is higher when the heating is switched on. The statistics show that the average carbon dioxide level in seven houses in the winter season is 867 ppm, while in the autumn season is 681 ppm. Therefore, heating systems' consumption increased carbon dioxide levels by approximately 22%. However, Zhao highlights that using heating in the winter season impacts the CO_2 levels in the house. According to their investigations, the carbon dioxide level difference between summer and winter seasons varied around 15-25%. In high temperatures, air conditioning is consumed to refresh the air in the house, and at night times windows are open till the morning. That aids in decreasing CO_2 concentration and release of accumulated pollutants outdoor. In winter, windows were closed for the day because of the heating system work and to stabilize the indoor temperature level. That's why the air circulation in the building is not functioning, which leads to the accumulation of carbon dioxide in the air.

CHAPTER 4 – CONCLUSION

Indoor air quality is of the utmost importance to humans, as they spend most of their time indoors— it became clear that the primary source of air pollutants generated from cooking in the kitchen. Furthermore, the highest accumulation of contaminants was detected at low temperatures outdoors in the winter. Two studies were conducted in rural areas of Kazakhstan to comprehend the living behaviors of people indoors at different periods of time. Mayatas and Shornak villages were chosen to be monitored in South Kazakhstan to analyze indoor levels of CO_2, PM2.5, PM10, and Formaldehyde concentrations. The first study was carried out to collect fundamental knowledge and experience for the final study, which was conducted in the winter season (January and February months). Three apparatuses were in use in order for the study to monitor the above-mentioned indoor air pollutants; temperature, humidity level, and thermal pictures of the building structure.

The monitoring process of the houses was applied by WHO's recommended procedures, comparing the monitored data with standards, constraints and limitations. Firstly, the information upon building structure, materials, and family size were collected in a questionnaire. Then, collected data on indoor air pollutants was compared with WHO's set standards. Furthermore, cooking details such as duration, meal's type, preparation procedure, and consumed ingredients were recorded. As a result, when compared to the standards, all three measuring contaminants exceed their restrictions during the cooking process. The accumulation rate is directly proportional to the building structure and cooking details. Therefore, higher pollutant accumulation is explained by the smaller volumes of the rooms dedicatef for cooking, longer duration of preparation of dishes, consumed gas plate number on the stove, and meal preparation method.

The relationship between indoor and outdoor air pollutants is vital for the healthy atmosphere in the house. According to WHO's guidelines, the I/O index should be in the range of 1.6-1.8. However, PM exceeds the recommendations in all seven examined houses except for House 5. In which the CO_2 concentration level is slightly closer to the I/O range of 1.8. During the process of cooking, the ratio of all three pollutants increased by 3-4 times. The decay in the amount of pollutants was observed after an hour of cooking, however, the decay rate still remained higher than the initial indoor air pollutants concentration. The effect of the heating system on indoor air quality is analyzed by comparing the carbon dioxide level between the two studies and periods. Therefore, the CO_2 level is higher when the heating is switched on, except in the case of house 6. The statistics show that the average carbon dioxide level in the winter season is 867 ppm, while in the autumn season, it is 681 ppm, which implies that heating systems' consumption increased carbon dioxide levels by 22%.

This research helps in comprehending the lifestyles and behaviors of rural area residents of Kazakhstan. It is understandable that the house owners aim to build a house while spending as little money as possible because of their limited budget which leads to inadequate ventilation systems that bring about pollutants. Since large families and children live in the house, a specialist must first agree upon the design and layout of the house with regards to better air conditioning. It is better for families to spend a little more money on an adequate layout of the house than to pay twice the price for health issues resulting from economizing on house’s design. To comprehend the emission and accumulation of indoor air contaminants impacted by cooking activities, pollutants' decay and diffusion should be adequately investigated and accurately analysed.

This thesis considers only one hour of monitoring after the cooking in the kitchen room. To analyze even more precisely, sensors must monitor for up to 5 hours to observe the decay processes of CO2, PM2.5, and PM10 and several sensors should be established for the diffusion and transfer of pollutants to the house's other rooms.

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