CUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Bayan SAADA

INDOOR AIR QUALITY EVALUATION AT MARKETPLACES IN ISTANBUL, TURKEY, DURING COVID-19 LOCKDOWN

ENVIRONMENTAL ENGINEERING DEPARTMENT

ADANA, 2021

ABSTRACT

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Year: 2021, Pages: 75
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Throughout the 2019 novel coronavirus (COVID-19) pandemic, Turkey used strict lockdown policies to contain illness transmission. While quarantine regulations improved outdoor air quality, they deteriorated indoor air quality.

This study shed insight on a time frame where people have spent their indoor times in places other than their homes.

With indoor air quality (IAQ) is regarded as one of the top five environmental threats to public health, the majority of factors affecting IAQ have been considered whenever possible.

For this study, Indoor air samples were obtained at four different marketplaces within 13 weeks during the COVID-19 Pandemic in Istanbul, Turkey. All indoor air quality data including carbon dioxide (CO_2), relative humidity (RH), temperature, particulate matter ($PM_{2.5}$, PM_{10}), and volatile organic compounds (VOCs) were collected.

Also, statistical analysis and explanations were conducted on all concentrations and compared to global guidelines.

Keywords: Indoor Air Quality, COVID-19, Lockdown, Marketplaces.

ÖZ

YÜKSEK LİSANS TEZİ

COVID-19 KARANTİNA DÖNEMİNDE İSTANBUL MARKETLERDE İÇ HAVA KALİTESİ DEĞERLENDİRMESİ

Bayan SAADA

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
ÇEVRE MÜHENDİSLİĞİ ANABİLİM DALI

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2019 yılında ortaya çıkan yeni koronavirüs (COVID-19) kaynaklı pandemi boyunca, pek çok ülke gibi Türkiye de hastalık bulaşmasını kontrol altına almak için katı karantina politikaları uyguladı. Uygulanan bu politikalar ve karantina düzenlemeleri dış hava kalitesini önemli ölçüde iyileştirirken, iç hava kalitesinde ise tam tersi yönde etkide bulundu.

Bu çalışma, belirli bir zaman aralığı içerisinde insanların evleri haricindeki iç mekanlarda geçirdikleri zamanlarla alakalı fikir vermektedir.

İç hava kalitesi (IHK), halk sağlığına yönelik en büyük beş çevresel tehditten biri olarak kabul edildiğinden, IHK'yi etkileyen faktörlerin çoğu çalışma boyunca mümkün olan her fırsatta dikkate alınmıştır.

Bu çalışma için, İstanbul - Türkiye'deki COVID-19 Pandemisi sırasında 13 hafta içinde dört farklı market yerinde iç mekan hava örnekleri alındı. Karbondioksit (CO_2), bağıl nem (RH), sıcaklık, partikül madde ($PM_{2.5}$, PM_{10}) ve uçucu organik bileşikler (VOC'ler) dahil tüm iç mekan hava kalitesi verileri toplandı.

Ayrıca, tüm veriler üzerinde istatistiksel analiz ve açıklamalar yapıldı ve bunlar küresel kılavuzlarla karşılaştırıldı.

Anahtar Kelimeler: İç Hava Kalitesi, Kovit-19, Karantina, Market.

EXTENDED ABSTRACT

Recently, indoor air quality has become a parameter needed to be emphasized in indoor environments. In these environments, pollutants from several sources affect health, comfort, and performance of employees in a negative way. Shopping places environments are highly polluted because of the following reasons, crowded places, short break times,

low ventilation, factors bringing pollutants from the outdoors, non-existence of windows and being visited on daily basis.

Indoor air sampling was conducted in the four marketplaces in Istanbul, Turkey. Four days a week for 13 weeks (52 days in total), with 4 separate sessions each day.

Particle concentrations Particulate Matter ($PM_{2.5}$, PM_{10}), Nitrogen dioxide (NO_2), Volatile Organic Compounds (VOCs), CO_2, temperature, and relative humidity were measured. Two-minute samples were collected during four sampling sessions.

Applying Results of Analysis of Variance (ANOVA) by marketplace on the collected data, demonstrated that for CO_2, $PM_{2.5}$ and PM_{10}, there is a statistically significant difference, where all p-values are less than 0.05, which means the ratio of these three pollutants is not the same for all marketplaces.

Analysis of Variance (ANOVA) by sampling session demonstrated that there is a statistically significant difference, as for all the five pollutants CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs, p-values were less than 0.05.

Nearly all sample sessions revealed that one marketplace had larger pollutant concentrations, which might be attributed to increased customer traffic as a result of more affordable prices.

Another marketplace had the lowest amounts of all pollutants, which might be attributed to proper ventilation and full adherence to COVID-19 marketplace regulations.

Maximum temperature readings were within ASHRAE winter guidelines. However, minimum temperature readings were slightly below ASHRAE winter guidelines, which may cause moderate discomfort to persons who prefer a warmer indoor atmosphere in the winter.

Relative humidity levels varied considerably, sometimes exceeding ASHRAE standards. The median value, on the other hand, was within ASHRAE recommendations.

Almost all pollutant concentrations were within ASHRAE recommendations.

ACKNOWLEDGEMENT

I cannot convey my gratitude enough to my compassionate Supervisor, Dr. Bulent SARI.

I would like to express my heartfelt gratitude for the educational opportunities; I appreciate your time and the influence you had on me during my studies.

To my entire family, I want to express my gratitude for all the love, support, and courage you have given me in order for me to be where I am today.

Finally, to my devoted, loving, and supportive husband, BEŞİR, your encouragement through difficult times is greatly appreciated and rightly noticed; without you, this research would not have been possible.

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LIST OF ABBREVIATIONS

ANOVA	: Analysis of Variance
ASHRAE	: The American Society of Heating, Refrigerating and Air-Conditioning Engineers
CO_2	: Carbon Dioxide
EPA	: Environmental Protection Agency
IAQ	: Indoor Air Quality
NO_2	: Nitrogen dioxide
PM	: Particulate Matter
RH	: Relative Humidity
SPS	: Sick Building Syndrome
SPSS	: IBM SPSS Statistics Software
PPB	: Part Per Billion
PPM	: Part Per Million
TVOC	: Total Volatile Organic Compound
VOC	: Volatile Organic Compound
WHO	: World Health Organisation

1. INTRODUCTION

Air pollution presents a serious risk to health and environment, from smog hanging over cities to smoke inside homes. Numerous health care providers are concerned about the role of environmental exposures in the development of numerous diseases. In 2012, the World Health Organization (WHO) estimated that ambient air pollution caused nearly seven million deaths, accounting for more than 10% of all-cause deaths and more than doubling previous estimates.

Among the various types of pollution, air pollution has been a major source of concern throughout the world due to its widespread nature, negative impact on the environment, and potential health hazards to humans.

The World Health Organization estimates that the combined impacts of outdoor and indoor air pollution result in around seven million premature deaths per year. Several health problems can occur as a result of outdoor air pollution, including those affecting the respiratory, cardiovascular, immune, hematological, neurological, and reproductive/developmental systems (Curtis et al., 2006). However, since they are typically inhaled through the mouth and nose, the majority of these issues revolve around the respiratory system. Specific population groups are more vulnerable to the effects of air pollution than others (Gold, 2008).

1.1. Indoor Air Pollution

Since the late 1970s, indoor air pollution has been a well-known problem, even at very low concentrations, it can have a detrimental effect on health. Similarly, it causes structural damage to buildings and considerable economic loss as a result of diminished and damaged vegetation and disease growth. Also, it can be fatal, ending in death (Qasim et al.,2014).

People spend about 90% of their time indoors (Mitova et al.,2020), indoor air pollution pollutants are often two to five times higher than outside air, and sometimes as high as 100 times higher (Hess-Kosa.,2011) Although with the continuous improvement of our quality of life in the twenty-first century, indoor air pollution has become a major source of concern, according to a previous study conducted by the Environmental Protection Agency EPA, indoor air pollution is one of the top five environmental health risks.

A variety of air pollutants have been identified indoors. These air pollutants can be inorganic, organic, biological, or even radioactive, and include NOx, SO_2, O_3, CO, volatile and semi-volatile organic compounds (VOCs), particulate matter (PM), radon, and microorganisms.

While a number of these pollutants are present in both indoor and outdoor contexts and originate outdoors, the air inside can be much more contaminated than the air outside (Settimo et al.,2020).

Indoor air can be polluted by a wide variety of components that come both indoors and outdoors (Zhang et al.,2003).

The World Health Organization (WHO) has addressed the significant impact on human health multiple times in various documents and meetings, with two papers in 2009 and 2018 that proposed that indoor air pollution is responsible for 3.8 million premature deaths per year, including the following:

- Pneumonia accounts for 27% of cases.
- 18% are stroke victims.
- 27% are affected with ischemic heart disease.
- 20% of the population suffers from chronic obstructive pulmonary disease (COPD).
- 8% die of lung cancer.

The other report indicates that indoor air pollution contributes to 2.7 percent of the global burden of the disease, which includes asthma, which affects approximately 235 million individuals globally (Luengas et al.,2015), other allergic disorders, cardiovascular diseases, dermatitis, mucosal irritation, central nervous system effects, or certain cancers.

Even if no symptoms are present, it is prudent to attempt to enhance the indoor air quality in houses. While contaminants found in indoor air could have a variety of negative effects, there is great uncertainty regarding the quantities or durations of exposure required to cause damage.

1.2. Pollutants and Comfort Elements

-Particulate Matter ($PM_{2.5}$, PM_{10}):

Particulate Matter is a term that refers to an airborne mixture of solid particles and liquid droplets. Certain particles, such as dust, dirt, soot or smoke, are sufficiently large or dark to be visible to the human eye. Others are so minute that they can be identified only with an electron microscope.

$PM_{2.5}$ (particulate matter less than 2.5 m in diameter) has been directly related to respiratory ailments and infections such as asthma, as well as cardiovascular and respiratory disorders such as lung cancer.

PM_{10} refers to particles with a diameter of less than 10 m. They pose a lower hazard than $PM_{2.5}$. They continue to produce respiratory infections and irritations. Whereas exposure for an extended period of time may result in pulmonary and cardiovascular disorders, as well as lung cancer.

-Nitrogen dioxide (NO_2):

Nitrogen dioxide (NO_2) is a dangerous pollutant that contributes to acid rain in a number of areas globally. The gas has a variety of adverse health consequences on individuals, including the formation of asthma and other respiratory infections and illnesses that cause swelling of the body's normal oxygen pathways.

-Carbon dioxide (CO_2):

At even lower levels, exposure to ambient CO_2 in interior spaces can have detrimental effects on the human body, resulting in health concerns such as inflammation, impaired cognitive functioning, and renal and bone disorders.

CO_2 levels rise in buildings with a higher occupant density and are diluted and removed from structures at a pace determined by the rate of outdoor air ventilation. Therefore, examining levels of CO_2 in indoor air can reveal information regarding occupant densities and outdoor air ventilation rates.

CO_2 concentrations in indoor air are typically between 500 and 1500 parts per million(ppm) (Seppänen et al.,1999), while CO_2 at these amounts is not generally considered dangerous.

Kajtár et al.(2003) and Satish et al.(2012) found that increasing the CO_2 concentration in the air to 3000 parts per million reduces human well-being and ability to concentrate attention.

-Volatile Organic Compounds (VOCs):

At standard room temperature, volatile organic compounds (VOCs) are organic substances with high vapor pressure.

Their high vapor pressure is due to their low boiling point, which results in a significant number of molecules evaporating or sublimating from the compound's liquid or solid state and entering the surrounding air, a property known as volatility.

The total of all VOCs referred to as TVOCs, is frequently used to evaluate whether chemical levels in air samples are elevated.

These levels frequently reflect the chance of occupant irritation and discomfort. The symptoms of exposure to TVOCs might range from mild discomfort to lethal levels

Moreover, studies indicate that extended exposure to VOCs in the indoor environment can raise the risk of relative leukemia and lymphoma (irigaray et al.,2007).

VOCs are restricted by legislation, particularly in areas with the highest concentrations.

While harmful VOCs are often not acutely hazardous, their cumulative long-term health impacts are significant.

Due to the low concentrations and the late onset of symptoms, research into VOCs and their effects are difficult.

Prolonged exposure to volatile organic compounds (VOCs) in the indoor environment can contribute to sick building syndrome (SBS). Indoors, VOCs are produced by new furnishings, wall coverings, and office equipment.

Temperature and Relative humidity:

Comfort elements such as temperature and humidity are critical for sustaining a healthy indoor air quality (Davis et al.,2016).

Thermal comfort is influenced by air temperature, surface temperature, air movement, relative humidity, and rate of air exchange (Ormandy and Ezratty.,2012).

The relative humidity (RH) of the air is the quantity of water vapor it holds in comparison to the amount it can hold at a given temperature (McCarthy et al.,2001).

Temperature and relative humidity have been proven to increase air pollutant concentrations due to the dense air that traps the contaminants (Bentayeb et al., 2015).

1.3. Indoor Air Quality

It is critical to understand the characteristics that affect indoor air quality and, consequently, human comfort and health.

According to the Texas Voluntary IAQ Guidelines for Government Buildings (2002), acceptable IAQ is defined as "the quality of air in an occupied enclosed space that is within a predetermined temperature and humidity comfort zone and does not contain air contaminants in sufficient concentration to have a detrimental effect on the occupants' health and comfort."

Numerous national organizations and significant global committees, such as the World Health Organization (WHO), have established standards and guideline values that correspond to desirable IAQ management. These rules and guidelines are implemented with the common goal of minimizing human exposure to specific respiratory air pollutants.

Table 1.1. Standards and Guidelines for Each Pollutant

Pollutant	Values
Carbon dioxide (CO_2)	15 000 ppm as 15–min average 5 000 ppm as 8–h average 1 000 ppm as 1-h average (WHO) 700 ppm above the outdoor level (ASHRAE standard 62)
$PM_{2.5}$	25 µg/m3 as 24–h average 10 µg/m3 as 1–y average (Who) 100 µg/m3 as 1–h average 40 µg/m3 as 8–h average (ASHRAE)
Pollutant	**Values**
PM_{10}	50 µg/m3 as 24–h average 20 µg/m3 as 1–y average (WHO) 150 µg/m3 as 24–h average 50 µg/m3 as 1–y average (ASHRAE)
Nitrogen dioxide (NO_2)	0.1 ppm (200 µg/m3) as 1–h average 0.02 ppm (40 µg/m3) as 1–y average (WHO) 3 ppm (5 600 µg/m3) as 8–h working day 5–d working week 0.05 ppm (100 µg/m3) as 1–y average 1 ppm (1 800 µg/m3) as 15–min average (ASHRAE)
Total Volatile Organic Compounds (TVOC)	200 µg/m3 + outside air concentration
Temperature	22.5–26.0 °C in summer (Comfort Level) 20.0–23.5 °C in winter (Comfort Level) (ASHRAE)
Relative humidity	40–60% in summer (Comfort Level) 30–60% in winter (Comfort Level) (ASHRAE)

All chemicals that induce adverse health effects when ingested also induce harmful health effects when inhaled into the body

The effect of these air pollutants on humans varies according on their toxicity, concentration, and duration of exposure, and may differ between individuals (Leung,2015).

Carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO_2), sulfur dioxide (SO2), and particulate matter are all common air contaminants that contribute to deteriorating IAQ ($PM_{2.5}$ and PM_{10}). Additional IAQ parameters connected with a thermal comfort zone include air temperature, velocity, and humidity levels (Abdulwahab et al, 2015).

Notable, Indoor air quality (IAQ) has come to be a major source of concern.

Due to Turkey's severe lockdown laws during the COVID-19 outbreak, residents spent the majority of their time indoors. Where they could only go out for daily necessities in the nearby marketplaces, concerned about running out of necessary supplies, resulted in people spending the majority of their outdoor time in marketplaces.

This has resulted in numerous retailers using social distancing strategies and modifying their in-store best practices to ensure the safety of their consumers.

The primary objective of this study is to identify potential factors affecting indoor air quality (IAQ) and to assess IAQ in Istanbul, Turkey, through the monitoring of indoor air parameters temperature, relative humidity (RH), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and total volatile organic compounds (TVOCs)) in various types of marketplaces.

This study particularly focused on indoor pollutants during the lockdown period. Where the primary aims are as follows:

1. Evaluation of whether the IAQ levels in marketplaces comply with the IAQ Guidelines.
2. Evaluation of whether chosen marketplaces have varying-parameter concentration levels.

3. Evaluation of all pollutant’s concentrations over a period of several work hours.
4. Comparing air quality levels on weekdays and weekends.

Also, the following hypotheses were examined in the study:

H0: There will be no statistically significant difference between sampling locations' 52-days median airborne particle ($PM_{2.5}$, PM_{10}, CO_2, NO_2 and VOCs) concentrations.

H0: There will be no statistically significant difference between sampling sessions in 52-days median airborne particle ($PM_{2.5}$, PM_{10}, CO_2, NO_2 and VOCs) concentrations indoors.

All concentration samples and sampling sessions were conducted during the lockdown period, and all results were prepared and analyzed with IBM SPSS Statistic (SPSS).

2. LITERATURE REVIEWS

Recently, organizations and countries throughout the world have shifted their focus to indoor air pollution and IAQ.

Lin and Peng in (2010) assessed the global state of awareness on PM_{10}, $PM_{2.5}$, and ultrafine particles in primary school classrooms with pupils ranging in age from 5 to 13 years. The study focuses on the sources, compositions, and health consequences of PM_{10} and $PM_{2.5}$, as well as classroom-related influencing factors such as building age, season, meteorological, ventilation rates, and indoor activities, as well as an examination of ultrafine particles. Additionally, primary school improvements are recommended.

For 12 hours, Branis et al.(2005) examined the correlation coefficient between PM_{10}, $PM_{2.5}$, and PM1 concentrations at three distinct sites in a classroom. PM_{10}, $PM_{2.5}$, and PM1 mass concentrations were determined during a 12-hour period. The filters were modified at 8 a.m. and 8 p.m. to account for student attendance and absence. Gravimetry was used to determine concentrations. For PM_{10}, $PM_{2.5}$, and PM1, the average indoor workday daytime concentrations were 42.3, 21.9, and 13.7 µg m−3, workday night concentrations were 20.9, 19.1, and 15.2 µg m−3, weekend daytime concentrations were 21.9, 18.1, and 11.4 µg m−3, and weekend night concentrations were 24.5, 21.3, and 15.6 µg m−3, respectively. PM_{10} mean, median, and maximum 12-hour indoor concentrations were higher on workdays throughout the daytime. The statistically significant result implies that human activity is a substantial source of particles indoors. Additionally, it demonstrates that outdoor particle concentrations have an effect on their indoor concentrations.

Ekmekcioglu and Keskin in (2007) have explained the concentration of indoor air particulate matter (PM_{10} and $PM_{2.5}$) was evaluated in this study in five elementary schools in Istanbul, Turkey. Four of them are located near a major route with a large volume of traffic. For public schools, weekday indoor mass concentrations of PM_{10} particles ranged from 132.1 6.6 to 289.6 14.5 g/m3, with an average of 221.5 11.1 g/m3; those of $PM_{2.5}$ particles ranged from 45.6 2.3 to 95.2 4.8 g/m3, with an average of 70.9 3.6 g/m3. Additionally, the World Health Organization's (WHO) PM_{10} and $PM_{2.5}$ concentration guidelines were exceeded.

Kuş et al. (2007) collected data on temperature, relative humidity, carbon dioxide, and particulate matter in 2007 at two different campuses in Şanlurfa, Turkey. Indoor and outdoor spaces were sampled concurrently, and the results were analyzed statistically and compared to international standards for indoor air quality. Indoor air quality was found to be more acceptable in the winter than in the summer. During the winter season, the central heating system was utilized. However, due to the high temperature and the absence of an air conditioning system, the air quality and comfort conditions in the classroom were extremely poor during the summer season. According to the findings, relative humidity was within an acceptable range during the winter season, but was extremely low during the summer season. Additionally, they observed that the indoor carbon dioxide concentration increased in direct proportion to the number of students during the winter season and that the source of particle matter was predominantly indoor rather than outdoor.

Furthermore, Pekey and Arslanbaş.(2007) during the summer of 2006 and the winter of 2006–2007, evaluated indoor, outdoor, and personal exposure to VOCs in 15 houses, ten offices, and three schools in Kocaeli. All VOC concentrations were determined during a 24-hour period using passive sampling. Indoor concentrations and personal exposure were significantly greater than those seen outside. In general, indoor concentrations of target compounds are more tightly associated with outdoor concentrations in the summer than they are in the winter.

Humidity, temperature, CO_2, NO_2, and TVOC (total volatile organic compounds) concentrations, as well as air exchange rates, were measured in 148 apartments in Sweden and 157 single-family residences (Langer et al.,2016). The results indicated that there is a correlation between selected component concentrations and the age, type, and location of the building and ventilation system. The air exchange rate, formaldehyde and TVOC concentrations were all greater in naturally ventilated houses than in mechanically ventilated buildings.

Dalian, China, was the location of the investigation. 550 residents completed a questionnaire survey (Kajtá et al., 2003).

In Washington and Idaho, Shendell et al.(2004) examined the relationship between CO_2 concentrations and student absences. (Mcleod et al., 2008) conducted a statistical analysis of the CO_2, temperature, relative humidity, and fungal spore total concentration in a school.

Smedje et al.(2006) measured PM_{10}, PM1, NO_2, and O3 concentrations in the indoor and outdoor environments of Swiss schools.

Emmerich et al.(2017) did a study based on numerous researchers that focuses on North American high-performance commercial buildings, where indoor pollutants were monitored, and typically included some measure of particulate matter (PM) and total volatile organic compounds (VOCs), but rarely included biological contaminants, semi-volatile organic compounds, or ozone. The authors discovered that the number of research is limited and that the IAQ measurements taken vary significantly. It was decided that more consistent studies on the economic, environmental, and health implications of ventilation and IAQ in commercial buildings are required and that we should adhere to IAQ principles during design, construction, and commissioning, as well as after occupancy.

Argunhan and Avci.(2018) conducted a study, the purpose of this study was to ascertain the indoor air quality of classrooms in Turkish institutions. The parameters for indoor air quality measurements were relative humidity, temperature, carbon dioxide, radon, and total particulate matter (PM0.5, PM1.0, $PM_{2.5}$, PM5.0, and PM_{10}).The results were analyzed and contrasted with global standards. As a result, indoor temperatures were found to be lower than regulations while carbon dioxide and particulate matter levels were above the maximum limit. Relative humidity, on the other hand, was within acceptable levels.

Du et al.(2015) evaluated the indoor air quality in Lithuanian and Finnish residential structures. measuring relative humidity, indoor temperature, CO_2, CO (carbon monoxide), PM (particulatematter), NO_2, formaldehyde, and volatile organic compounds (VOCs).The results indicated that the majority of the parameters examined were within the recommended limits.Indoor $PM_{2.5}$, PM_{10}, formaldehyde, and relative humidity were found to be slightly higher in the unsatisfied group than in the satisfied group in Finland, whereas $PM_{2.5}$, NO_2, and relative humidity were found to be slightly higher in the unsatisfied group in Lithuania, but the differences were not statistically significant. While CO_2 concentrations were significantly higher in the unsatisfied group (1086 ± 230 ppm) than in the satisfied group (940 ± 360 ppm) in Lithuania.

Babayıgıt et al.(2014) determined the concentrations of several indoor air pollutants (sulfur dioxide, nitrogen dioxide, formaldehyde, carbon dioxide, and carbon monoxide) in 172 classrooms across 31 primary schools in Keçiören, Ankara, in order to establish a link between IAQ and health.

Moreover, CO_2 concentrations were utilized as an indicator of indoor air quality in 79 Greenlandic dwellings, in which indoor temperature and humidity were recorded in bedrooms. Similarly, newer residential buildings had higher CO_2 and moisture concentrations than residences built prior to 1990 (Strachan et al.,1989).

There is strong evidence that in schools, CO_2 concentrations are frequently near or above the levels associated in this study with significant reductions in decision-making performance. In surveys of elementary school classrooms in California and Texas, average CO_2 concentrations were > 1,000 ppm, a substantial proportion exceeded 2,000 ppm, and in 21% of Texas classrooms peak CO_2 concentration exceeded 3,000 ppm (Corsi et al. 2002; Whitmore et al. 2003)

Tortolero et al.(2002) evaluated the IAQ in selected primary schools in southeast Texas using data from an environment observation checklist survey, ventilation monitoring, and dust sampling. They discovered that 86% of classrooms had CO_2 levels over the permissible level, which could imply that the ventilation rate is lower than the required rate. 69 percent of classrooms had a relative humidity level above the acceptable limit, which might encourage mold growth. They suggested that classroom carpeting may lead to the growth of mold and dust mites.

Godwin et al.(2006) surveyed 21 elementary schools, five middle schools, and three high schools in southeast Michigan to determine the air quality in classrooms used for a variety of purposes (art, science, office, computer, and music) both within and between schools. Bioaerosols, VOCs, CO_2, relative humidity, and temperature were monitored in each classroom for one workweek; VOCs, bioaerosols, temperature, and relative humidity were monitored outdoors; outdoor samples were taken at rooftop locations at each school, and a comprehensive walk-through survey was completed. They discovered that within-school variability in CO_2, VOC, and bioaerosol concentrations was greater than between-school variability. CO_2 values in the majority of classrooms surpassed 1000 parts per million. There were low amounts of VOCs and bioaerosols detected, as well as appropriate temperature and relative humidity limits. Bioaerosol was associated with the presence of carpeting. The highest quantities of VOCs were seen in science and art areas.

Bayer et al.(1999) investigated the factors affecting the indoor air quality in schools. There appears to be an association between IAQs and the percentage of kids from low-income households at a school. 36% of households lack sufficient heating, ventilation, and air conditioning (HVAC) systems. Proper outdoor air ventilation and humidity management were discovered to be important. Additionally, IAQ concerns in schools can be avoided by providing continuous outdoor air circulation, maintaining a space relative humidity of 30% to 60%, and providing good particulate filtration of the outdoor air.

Hazar et al.(2014) assessed health care providers' perceptions of the risk of exposure to indoor household radon. In various indoor locations, pollutants were identified and their health consequences assessed.

Hwang and Kim.(2013) conducted an assessment of the indoor air quality in open-plan offices, While Tan et al.(2013) examined the indoor air pollution emissions caused by residential building energy use.

Bucur et al.(2015) evaluated the indoor air quality in a Bucharest wooden church.

Xiang et al.(2016) examined the indoor air quality in kitchens equipped with traditional non-chimney stoves and improved non-chimney stoves.

Whereas Zong et al.(2012) measured particulate matter of a diameter smaller than 2.5 micrometers, elemental carbon, and organic carbon in a rural setting and nonsmoking household's kitchen, bedroom, and outdoors.

The adverse effects are not only dependent on pollution, but also on the ambient temperature and humidity. Studies have shown that Warm and humid air is stuffy (Berg et al., 1980), and in the winter, room air temperature generates a greater number of classic sick building syndrome (SBS) symptoms than cooler air (Seppäanen et al.,1980).

From the standpoints of indoor air quality and energy efficiency, studies by Fang et al.(1998) While Humphreys et al.(2002) advised using low room air temperature and low relative humidity in the winter.A sensation of dryness in the air is another critical subjective indicator of indoor air quality. The higher amount of air pollution was found to be a more significant impact in the experience of "dryness" than the low relative air humidity (Wang et al.,2013).

Lin et al.(2014) discovered that the impression of air dryness was most prevalent (57.4 percent) among the participants in a study in China.

The health consequences of poor IAQ are complex and depend on a variety of parameters, including the effect of each contaminant, the concentration, the duration of exposure, and individual susceptibility (Hess-Kosa., 2010). Contaminants in indoor air can cause acute or chronic health concerns.

-Numerous studies have been conducted on the relationship between indoor air pollution and health outcomes, and the majority of them reveal a negative association.

Liu et al.(1991) investigated the connection between indoor air pollution and lung cancer in China using a sample of 436 persons. They discovered that indoor coal consumption is related to an increased risk of lung cancer.

Similarly, Qian et al.(2008) showed that coal smoke from cooking and heating is connected with a variety of respiratory problems, including asthma and persistent coughing.

Another research indicates that air pollution exposure can result in a variety of physical health concerns, including hypertension, lung cancer, and respiratory disorders (Green et al.,2010, Munroe et al.,2012, Baumgartner et al.,2011; Chen et al. 2018; Wang et al.,2018).

Qasim et al.(2013) discovered that indoor pollution has specific health consequences. These health consequences of indoor biomass burning, particularly in rural regions, include Acute Respiratory Infections in children, Lung Cancer, Tuberculosis, and adverse pregnancy outcomes, with youngsters being more prone to health consequences than older adults. It was discovered that several prevalent infections and disorders were examined in the dwelling of Sabour village, with 50.3 percent of family members having Chronic Obstructive Pulmonary Disease. 12.7 percent of respondent's family members had a respiratory infection, 9.6 percent had asthma, and 6.4 percent had lung cancer.

Similarly, Qiu et al.(2019) examined the health consequences of indoor air pollution caused by heating or cooking in middle-aged and older persons using data from the 2013 China Health and Retirement Longitudinal Study (CHARLS).They discovered that exposure to indoor air pollution greatly increases the risk of being diagnosed with respiratory and cardiovascular disorders such as lung disease, heart disease, and hypertension, as well as reporting poor health status.

Other research indicates that exposure to indoor air pollution has a deleterious influence on cognitive ability in addition to physical and health disorders (Gauvain 2012; Krishnamoorthy et al., 2018; Saenz et al.,2018) Cognitive decline has a significant impact on the middle-aged and older populations, who frequently face complex high-stakes economic and financial decisions such as investment and retirement planning.

Additionally, cognitive impairment is a risk factor for dementia in the senior population, such as Alzheimer's disease, resulting in significant social expenses (Bishop et al., 2018).

Other studies demonstrate that exposure to air pollution is associated with diminished cognitive performance (Zhang et al.,2018).

Babu and Vimalanathd.(2014) Studied The effect of indoor environments on office workers' performance, productivity, health, and well-being.

Whereas, formaldehyde and CO_2 concentrations were measured, and a clear association was discovered between growing indoor CO_2 concentrations and breathing difficulties, headaches, and stuffy air for inhabitants (Kotol et al.,2014). Whereas some studies concluded that CO_2 is a major regulator of human respiration and behavioral arousal (Kaye et al., 2004).

There is a positive link between mortality (or morbidity) and a variety of frequently measured pollutants, including nitrogen dioxide (Zmirou et al.,1998), carbon monoxide (Tao et al., 2012), ozone (Verhoeff et al.,1996), and particulate matter (Zmirou et al., 1996;Laden et al.,2000).

Wei Du et al.(2021) conducted a study that constantly assessed real-time $PM_{2.5}$ levels in indoor rooms such as the kitchen and living room during the coronavirus (COVID-19) pandemic. and also investigate the outdoors in rural households in China during two distinct periods: normal days (Period-1) and the days of COVID-

19 lockdown in China (Period-2). The average daily $PM_{2.5}$ concentrations in the kitchen and living room increased by 17.4 and 5.1 mg/m3, respectively, during Period-2, which may be related to higher fuel use for cooking and heating due to higher family numbers than on regular days. Whereas, the ambient $PM_{2.5}$ concentration reduced by 6.7 mg/m3 in rural regions during Period-2, this was smaller than the decrease in urban areas (26.8 mg/m3). Daily personal exposure to $PM_{2.5}$ was 134 ± 40 mg/m3 in Period-2, which was substantially higher than it was in Period-1 (126 ± 27 mg/m3, $p < 0.05$). This was due to increased indoor air pollution and increased time spent in indoor surroundings. This rise has a detrimental effect on human health, which is why additional research should be conducted to determine the health consequences of a global COVID-19 lockdown on communities.

Additionally, to these studies, concentrating on indoor air quality in a variety of situations, this inquiry attempts to demonstrate some of the most prevalent indoor air pollutants in marketplaces and to make some recommendations for improving indoor air quality.

3. MATERIALS AND METHODS

3.1. Materials

The 77535 AZ is a portable CO_2 sensor that was used to measure CO_2 concentration, air temperature, dew point and humidity, it can measure CO_2 with the range 0~9999 ppm, with the resolution of 1 ppm, an accuracy of ±30 ppm ±5% of reading (0~5000 ppm), and it required 30 seconds for CO_2 Warm-up.

For the Temperature, it measures it within the range of -10~60℃, a resolution of 0.1℃, an accuracy of ±0.6℃, and response time of ＜2 mins.

While for the relative humidity, the range was 0.1~99.9% RH, with a resolution of 0.1% RH, an accuracy of ±3%RH (at 25℃, 10~90%RH); others ±5%RH and a response time of ＜10 mins.

Figure 2.1**.** 77535-AZ CO_2 Sensor

Flow is an air pollution sensor that uses artificial intelligence and neural networks, designed to track air quality both indoors and outdoors. Every 60 seconds the device provides concentration estimates of the following pollutants: Particulate Matter ($PM_{2.5}$, PM_{10}), Nitrogen dioxide, Volatile Organic Compounds (VOCs), with a coefficient correlation of 95% for NO_2, 68.6% for VOC, 95% for $PM_{2.5}$, and 88% for PM_{10}.

Flow connects to an application installed on a mobile device (iOS) using Bluetooth to show the results in real-time, data presented in the app was using the Plume Index and was converted using the plume cloud data extraction service.

Figure 2.2. Flow Tracker by Plum Labs

3.2. Methods

3.2.1. Sampling Locations

Air measurements were conducted at four marketplaces referenced as Market-1, Market-2, Market-3 and Market-4, all located in the Kadikoy area in Istanbul, Turkey.

Each of these marketplaces is connected to a wider marketplace chain. Two of the marketplaces were moderate size. Whereas the other two were substantial.

Each marketplace's capacity indicates the maximum number of individuals that can be present at the same time due to the regulations of the COVID-19 pandemic.

All marketplaces shared the same ventilation, internal conditions, and operating hours.

Table 3.1. Description of Sampling Locations

Marketplace Reference	Area (m^2)	Capacity (person)
Market-1	600 m^2	60
Market-2	200 m^2	20
Market-3	180 m^2	18
Market-4	580 m^2	58

3.2.2. Sampling Session:

Sampling took place for 13 weeks, between 21/12/2020 and 20/3/2021, primarily during the winter season; each week, four days were chosen in total, with one being a weekend.

Sampling sessions were chosen to collect data during periods of possible high activity and a period of low activity for the baseline. The four-time periods (Sampling Sessions) were as follows:

1. Morning baseline: approximately 10:00-12:00, marketplaces opened their doors at 10:00 during the lockdown, samples were collected earliest possible.
2. Noon lunchtime: approximately 12:00-14:00. most employers' lunch break occurs at this time period.
3. Afternoon baseline: approximately 14:00-16:00.
4. Evening: approximately 16:00-18:00 mostly the time around closing hours, usually a time when shoppers rushed to obtain their groceries before stores closed, this period has been replaced by an average of the three other weekend periods due to earlier lockdown hours.

All calibrations were carried out in accordance with the manufacturer's specifications. All equipment was mounted on a shopping cart at roughly waist level, All equipment's inlets were positioned far from all walls and corners and toward the middle of the marketplace.

Equipment was configured to capture a two-minute average sample, which was presented on-screen for 77535-AZ and on the mobile screen for Flow.

The data obtained were recorded on a sampling sheet. All sampling data, such as location, weather conditions, time, Particulate Matter ($PM_{2.5}$, PM_{10}), Nitrogen dioxide, Volatile Organic Compounds (VOCs), CO_2, temperature, and relative humidity, were recorded on a single form.

3.2.3. Data Analysis

All data were exported and downloaded into excel from Flow cloud service, while data from 77535-AZ were collected manually in a separate excel after every measurement.

For analysis, data were combined into a single SPSS file, and all analyses were conducted using IBM SPSS Statistics 26.

The mean, median, minimum, maximum, and standard deviation were calculated for each marketplace, sampling location, weekend/weekday, and pollutant type. Because the data were normally distributed, no changes are required for the subsequent analysis. Following the descriptive statistics, we use data visualization techniques such as boxplots, clustered bar plots, and line charts to get an insight into median differences between the different groups.

Analysis of variance (ANOVA), a parametric test, was used to assess if there are any statistically significant differences in the means of two or more independent groups (Marketplace, Pollutant, Sampling Session). On significant ANOVA findings, the Tukey honestly significant difference (HSD) post hoc test was used to determine statistically significant pairwise differences between marketplaces and Sampling Sessions. All analyses were conducted with a significance level of = 0.05.

4. RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics:

In this chapter, descriptive statistics were used to analyze all data, with a particular emphasis on the relationships between pollutants and marketplace, sample sessions, and weekends/weekdays.

4.1.1. Descriptive Statistics All Samples by Marketplace

Table 4.1 shows the descriptive statistics for pollutants by marketplace. The temperature ranged from 13.10 and 22.6 °C, while relative humidity ranged from 20.38% to 86.53%.

Market-2 had the highest median of CO_2 (930.67 ppm), $PM_{2.5}$ (30.32 µg/m3), PM_{10} (54.50 µg/m3) and VOCs (74.50 ppb), Market-3 had the highest median of NO_2(17.00 ppb).
Market-4 on the other hand, had the lowest median of all measured pollutants, CO_2 (657.50 ppm), NO_2 (15.00 ppb), $PM_{2.5}$ (15.13 µg/m3), PM_{10} (43.64 µg/m3) and VOCs (67.50 ppb).

Table 4.1. Descriptive Statistics All Samples by Marketplace

		Mean	Median	Minimum	Maximum	Std. Deviation
Market-1	CO_2	805.36	778.00	466.00	1292.00	205.98
	NO_2	16.21	16.00	3.00	37.00	5.41
	$PM_{2.5}$	26.54	27.69	5.13	46.31	11.60
	PM_{10}	54.25	53.53	9.72	109.29	24.38
	RH%	51.06	53.10	25.91	71.87	10.96
	TEMP	18.10	18.20	13.30	21.60	1.48
	VOCs	79.52	73.00	16.00	350.00	42.07

Table 4.1. Descriptive Statistics All Samples by Marketplace (continue)

		Mean	Median	Minimum	Maximum	Std. Deviation
Market-2	CO_2	945.58	930.67	512.00	1391.00	186.78
	NO_2	16.43	16.00	.00	32.00	5.44
	$PM_{2.5}$	28.06	30.32	6.52	50.70	11.05
	PM_{10}	56.06	54.50	8.54	109.45	24.96
	RH%	53.97	55.69	31.25	86.53	11.80
	TEMP	17.18	17.17	13.10	21.10	1.50
	VOCs	98.98	74.50	4.00	2500.00	200.17
Market-3	CO_2	709.02	668.00	463.00	1283.00	151.71
	NO_2	16.72	17.00	3.00	30.00	4.90
	$PM_{2.5}$	21.21	19.64	1.08	48.01	11.78
	PM_{10}	51.13	51.91	2.40	106.44	23.90
	RH%	54.59	56.14	29.67	79.20	10.98
	TEMP	16.87	16.80	14.20	21.50	1.42
	VOCs	78.50	72.00	11.00	898.00	73.75
Market-4	CO_2	680.33	657.50	460.00	1196.00	126.97
	NO_2	15.79	15.00	4.00	31.00	4.97
	$PM_{2.5}$	15.84	15.13	3.53	38.16	7.89
	PM_{10}	44.07	43.64	4.38	108.90	21.04
	RH%	46.31	47.36	20.38	68.43	10.37
	TEMP	19.99	20.10	16.30	22.60	1.16
	VOCs	73.56	67.50	3.00	320.00	40.33
Total (All Marketplaces)	CO_2	785.07	754.00	460.00	1391.00	199.38
	NO_2	16.29	16.00	.00	37.00	5.19
	$PM_{2.5}$	22.91	21.82	1.08	50.70	11.71
	PM_{10}	51.38	51.05	2.40	109.45	24.02
	RH%	51.48	52.86	20.38	86.53	11.49
	TEMP	18.03	18.10	13.10	22.60	1.85
	VOCs	82.64	73.00	3.00	2500.00	110.80

4.1.2. Descriptive Statistics by Sampling Sessions

4.1.2.1. Descriptive Statistics by Sampling Sessions All Marketplaces

Table 4.2 describes the indoor median, minimum and maximum values for each Sampling Session,

The highest median of CO_2 (819 ppm), NO_2 (18.00 ppb), $PM_{2.5}$ (25.41 µg/m3), PM_{10} (75.94 µg/m3) and VOCs (79.50 ppb) were noticed in the 16-18 sampling session.

However, lowest median of CO_2 (682.39 ppm), NO_2 (13.85ppb), $PM_{2.5}$ (17.67 µg/m3), PM_{10} (39.66 µg/m3), VOCs (61.09 ppb) were noticed in 10-12 sampling session.

Table 4.2. Descriptive Statistics by Sampling Session, All Marketplaces.

Session		Mean	Median	Minimum	Maximum	Std. Deviation
10-12	CO_2	682.39	644.50	460.00	1284.00	159.09
	NO_2	13.85	14.00	3.00	29.00	4.27
	$PM_{2.5}$	17.67	15.62	4.81	41.57	9.95
	PM_{10}	39.66	35.56	5.46	106.58	19.68
	RH%	53.45	55.19	22.43	78.28	12.14
	TEMP	17.41	17.30	13.30	21.10	1.66
	VOCs	61.09	49.50	4.00	620.00	52.49
12.-14	CO_2	832.38	806.50	500.00	1299.00	187.39
	NO_2	16.72	17.00	3.00	30.00	4.64
	$PM_{2.5}$	25.64	24.47	5.13	48.83	11.63
	PM_{10}	57.42	56.34	13.43	109.29	23.28
	RH%	51.28	52.44	24.80	86.53	11.39
	TEMP	18.09	18.00	13.60	22.30	1.91
	VOCs	87.11	78.00	10.00	1181.00	91.57

Table 4.2. Descriptive Statistics by Sampling Session, All Marketplaces (continue)

Session		Mean	Median	Minimum	Maximum	Std. Deviation
14-16	CO_2	770.89	748.50	463.00	1287.00	194.09
	NO_2	16.61	15.50	3.00	31.00	5.69
	$PM_{2.5}$	22.79	21.65	5.47	48.59	11.76
	PM_{10}	50.13	46.50	4.38	108.96	25.63
	RH%	50.65	52.55	20.38	75.57	11.10
	TEMP	18.27	18.20	13.50	22.60	1.79
	VOCs	89.99	75.50	15.00	2500.00	171.75
16-18	CO_2	854.63	819.00	483.00	1391.00	208.78
	NO_2	17.97	18.00	.00	37.00	5.17
	$PM_{2.5}$	25.55	25.41	1.08	50.70	11.67
	PM_{10}	58.30	57.94	2.40	109.45	22.47
	RH%	50.55	50.96	22.47	79.74	11.16
	TEMP	18.38	18.50	13.10	22.30	1.89
	VOCs	92.39	79.50	3.00	900.00	89.50
Total (All sessions)	CO_2	785.07	754.00	460.00	1391.00	199.38
	NO_2	16.29	16.00	.00	37.00	5.19
	$PM_{2.5}$	22.91	21.82	1.08	50.70	11.71
	PM_{10}	51.38	51.05	2.40	109.45	24.02
	RH%	51.48	52.86	20.38	86.53	11.49
	TEMP	18.03	18.10	13.10	22.60	1.85
	VOCs	82.64	73.00	3.00	2500.00	110.80

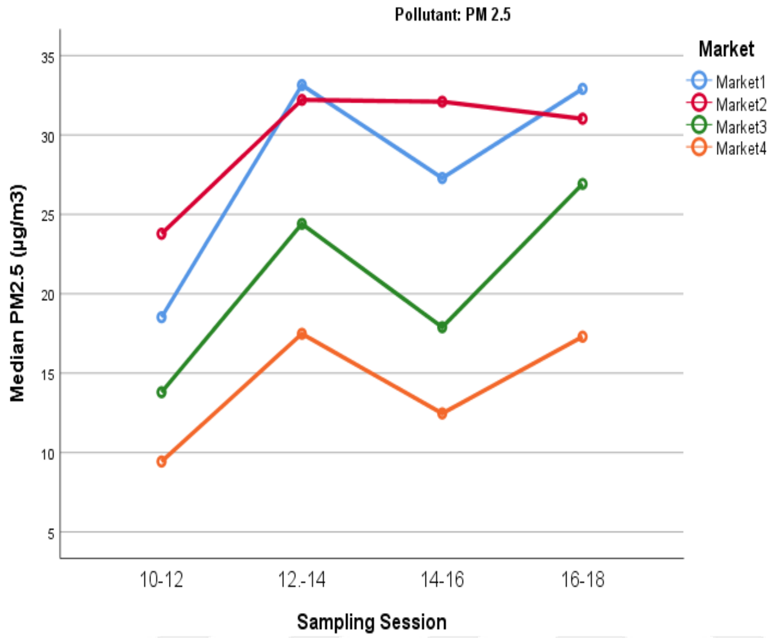

Figure 4.1. Median $PM_{2.5}$ Concentrations by Sampling Session

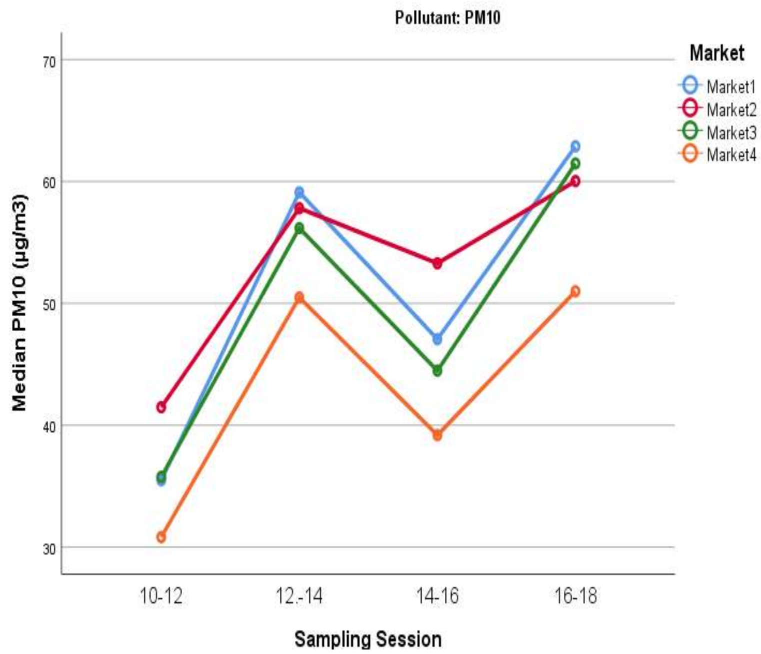

Figure 4.2. Median PM_{10} Concentrations by Sampling Session

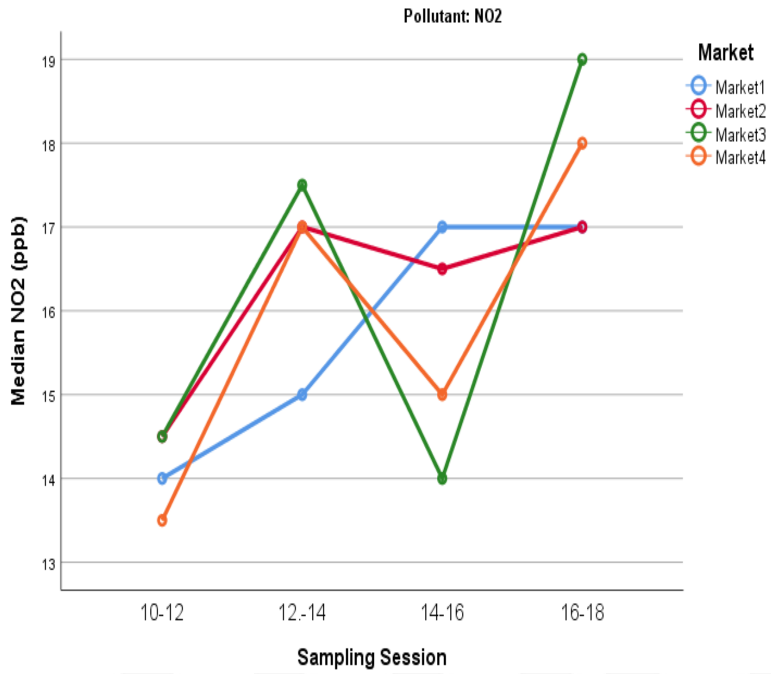

Figure 4.3. Median NO_2 Concentrations by Sampling Session

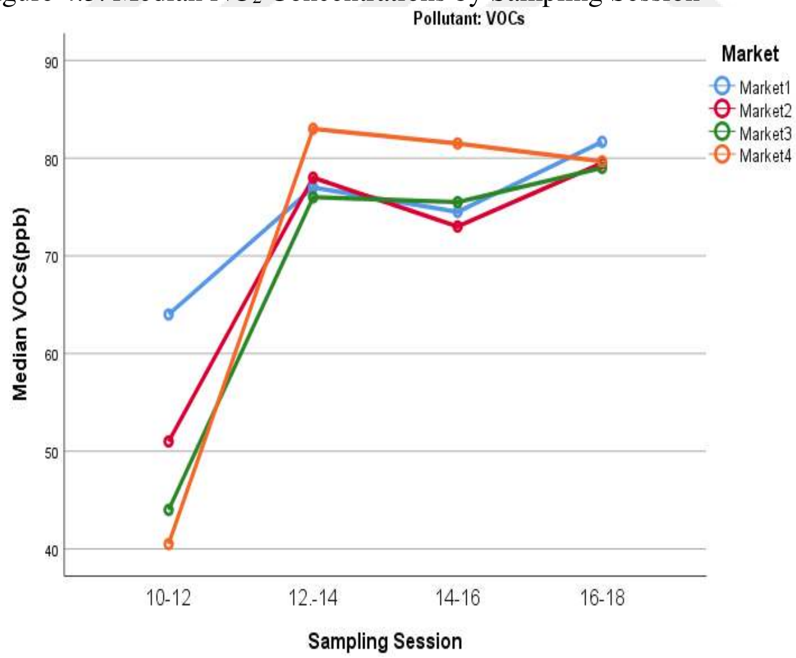

Figure 4.4. Median VOCs Concentrations by Sampling Session

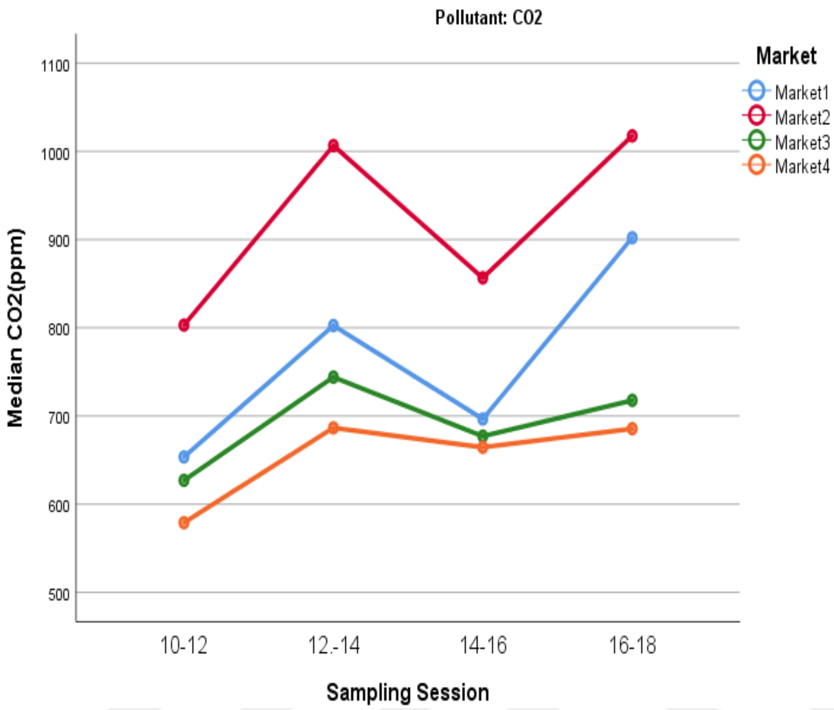

Figure 4.5. Median CO_2 Concentrations by Sampling Session

4.1.2.2. Descriptive Statistics by Sampling Sessions by Market-1

For Market-1, temperature was between 13.30 and 21.60 °C, while relative humidity ranged between 25.91% and 71.87%.

Highest median of CO_2 (902 ppm), PM_{10} (62.88 µg/m3) and VOCs (81.67 ppb) were in the session 16-18, while highest median of $PM_{2.5}$ (33.14 µg/m3) was in session 12-14.

While highest NO_2 median (17.00 ppb) was noticed in two different session, 14-16 and 16-18.

Table 4.3. Descriptive Statistics by Sampling Session, Market-1

Session		Mean	Median	Minimum	Maximum	Std. Deviation
10-12	CO_2	687.54	653.50	490.00	1176.00	154.98
	NO_2	14.00	14.00	3.00	24.00	4.40
	$PM_{2.5}$	19.93	18.52	5.27	41.57	11.62
	PM_{10}	39.31	35.49	9.72	84.59	19.75
	RH%	53.08	56.22	27.36	71.87	12.08
	TEMP	17.47	17.45	13.30	19.50	1.16
	VOCs	70.13	64.00	16.00	230.00	40.73
12.-14	CO_2	855.85	802.50	516.00	1292.00	178.37
	NO_2	15.40	15.00	3.00	29.00	4.88
	$PM_{2.5}$	29.65	33.14	5.13	46.04	11.95
	PM_{10}	58.78	59.11	15.31	109.29	23.37
	RH%	50.93	53.04	27.92	70.68	10.90
	TEMP	18.23	18.30	13.60	20.80	1.60
	VOCs	86.88	77.00	21.00	350.00	48.49
14-16	CO_2	766.02	696.50	466.00	1287.00	226.71
	NO_2	17.29	17.00	5.00	30.00	5.67
	$PM_{2.5}$	26.86	27.29	5.96	43.38	10.11
	PM_{10}	56.72	47.06	12.65	105.74	28.92
	RH%	50.27	52.89	25.91	69.62	10.70
	TEMP	18.17	18.30	13.50	21.00	1.44
	VOCs	77.13	74.50	17.00	225.00	44.30
16-18	CO_2	912.03	902.00	494.00	1266.00	187.20
	NO_2	18.16	17.00	7.00	37.00	5.71
	$PM_{2.5}$	29.72	32.90	7.47	46.31	10.08
	PM_{10}	62.20	62.88	12.12	93.23	17.92
	RH%	49.96	50.40	27.28	70.45	10.14
	TEMP	18.54	18.57	13.80	21.60	1.52
	VOCs	83.94	81.67	17.00	178.33	32.23
Total (All Sessions)	CO_2	805.36	778.00	466.00	1292.00	205.98
	NO_2	16.21	16.00	3.00	37.00	5.41
	$PM_{2.5}$	26.54	27.69	5.13	46.31	11.60
	PM_{10}	54.25	53.53	9.72	109.29	24.38
	RH%	51.06	53.10	25.91	71.87	10.96
	TEMP	18.10	18.20	13.30	21.60	1.48
	VOCs	79.52	73.00	16.00	350.00	42.07

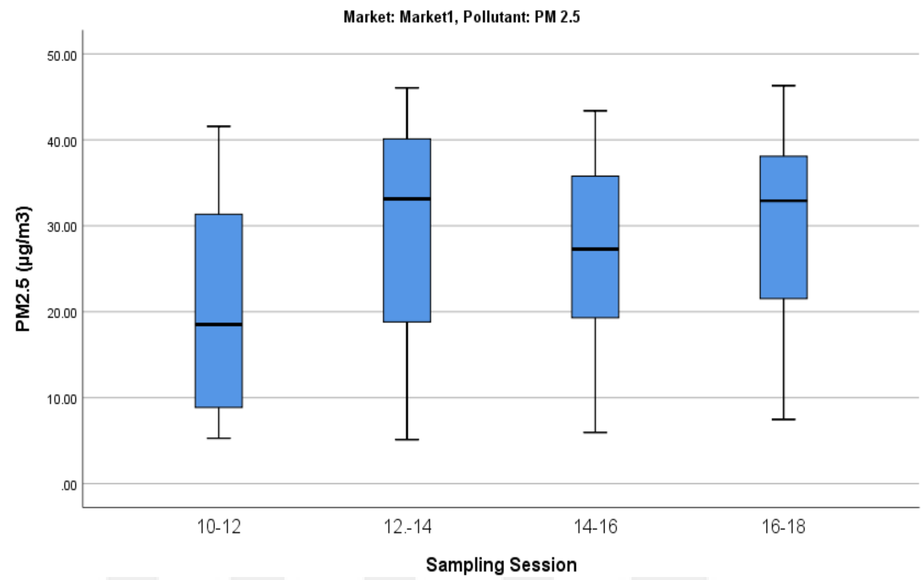

Figure 4.6. $PM_{2.5}$ concentration by sampling session market-1

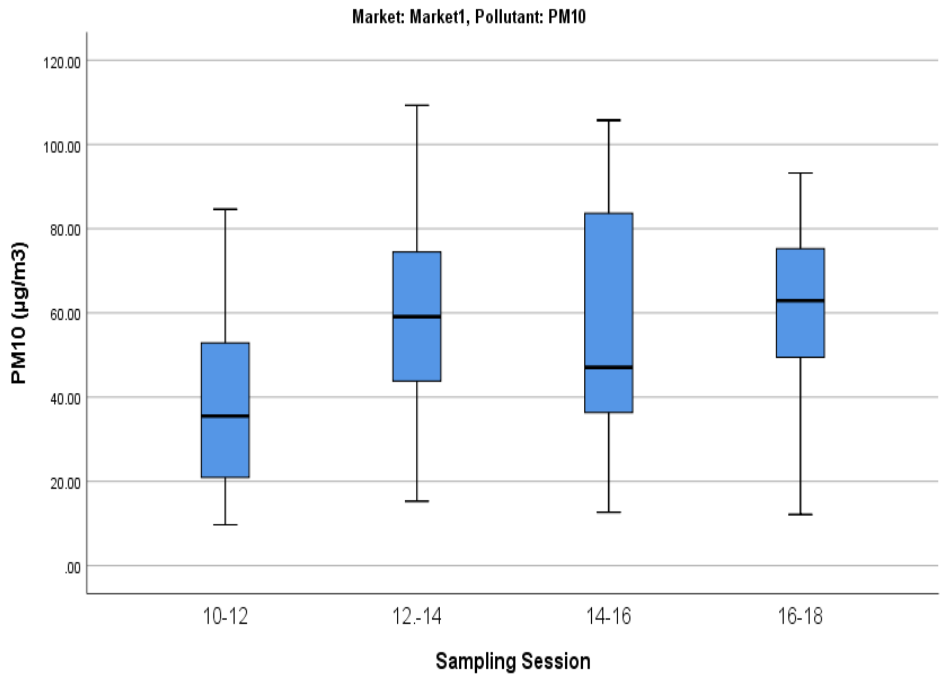

Figure 4.7. PM_{10} Concentration by Sampling Session Market-1

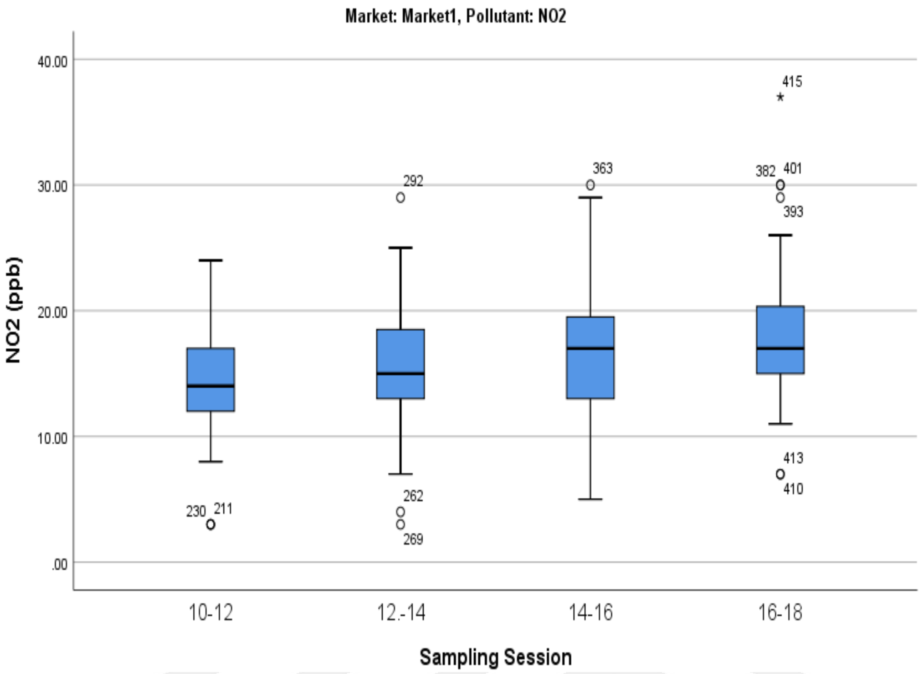

Figure 4.8. NO_2 Concentration by Sampling Session Market-1

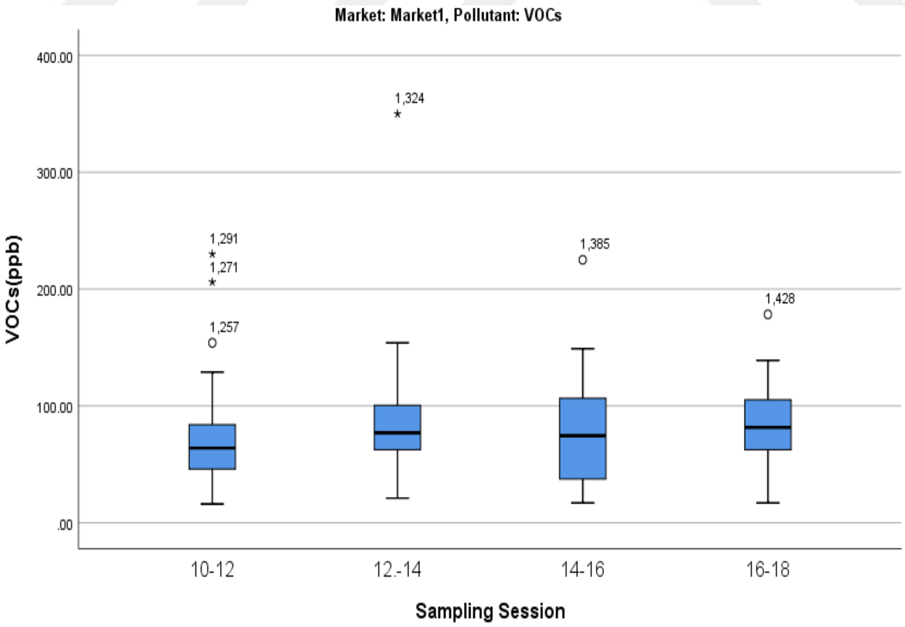

Figure 4.9. VOCs Concentration by Time Period Market-1

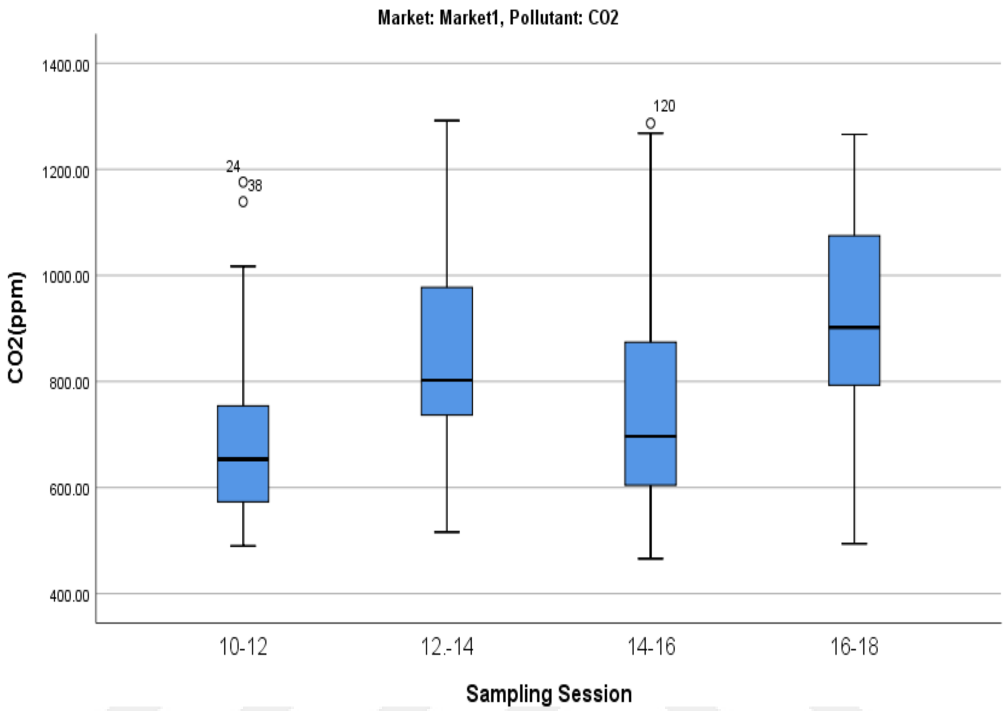

Figure 4.10. CO_2 Concentration by Sampling Session Market-1

4.1.2.3. Descriptive Statistics by Sampling Sessions by Market-2

For Market-2, temperature was between 13.10 and 21.10 °C, while relative humidity ranged between 31.25% and 86.53%.

Highest median of CO_2 (1017.50 ppm), VOCs (79.50 ppb) and PM_{10} (60.03 µg/m3) were in 16-18 session, while lowest median of CO_2 (803.00 ppm), VOCs (51.00 ppb), $PM_{2.5}$ (23.78 µg/m3) and PM_{10} (41.48 µg/m3) was in 10-12 session.

$PM_{2.5}$ highest median (32.21 µg/m3) was noticed in 12-14 session, NO_2 had same highest median (17.00 µg/m3) in12-14 and 16-18 sessions.

Table 4.4. Descriptive Statistics by Sampling Session, Market-2.

Session		Mean	Median	Minimum	Maximum	Std. Deviation
10-12	CO_2	833.02	803.00	512.00	1284.00	159.33
	NO_2	14.17	14.50	3.00	23.00	3.96
	$PM_{2.5}$	23.07	23.78	6.52	39.87	9.78
	PM_{10}	45.04	41.48	15.48	106.58	21.55
	RH%	56.67	57.78	31.25	77.12	12.22
	TEMP	16.38	16.30	14.10	19.20	1.25
	VOCs	70.21	51.00	4.00	620.00	85.41
12.-14	CO_2	1013.31	1006.50	718.00	1299.00	134.72
	NO_2	17.23	17.00	10.00	30.00	5.00
	$PM_{2.5}$	30.01	32.21	10.75	48.83	10.60
	PM_{10}	62.63	57.81	15.93	107.30	23.59
	RH%	53.97	54.96	31.52	86.53	11.87
	TEMP	17.11	17.15	14.30	21.10	1.43
	VOCs	93.94	78.00	10.00	1181.00	157.84
14-16	CO_2	898.37	856.50	649.00	1286.00	177.83
	NO_2	16.60	16.50	5.00	29.00	5.29
	$PM_{2.5}$	28.86	32.09	7.22	48.59	10.57
	PM_{10}	53.61	53.29	12.36	108.96	24.73
	RH%	52.77	55.45	32.30	75.57	11.11
	TEMP	17.64	17.80	14.80	20.70	1.35
	VOCs	122.90	73.00	20.00	2500.00	337.71
16-18	CO_2	1037.62	1017.50	531.00	1391.00	194.78
	NO_2	17.74	17.00	.00	32.00	6.62
	$PM_{2.5}$	30.29	31.02	8.70	50.70	11.90
	PM_{10}	62.96	60.03	8.54	109.45	25.96
	RH%	52.45	54.33	31.42	79.74	11.85
	TEMP	17.57	17.37	13.10	20.60	1.63
	VOCs	108.87	79.50	31.00	900.00	121.76
Total (All Sessions)	CO_2	945.58	930.67	512.00	1391.00	186.78
	NO_2	16.43	16.00	.00	32.00	5.44
	$PM_{2.5}$	28.06	30.32	6.52	50.70	11.05
	PM_{10}	56.06	54.50	8.54	109.45	24.96
	RH%	53.97	55.69	31.25	86.53	11.80
	TEMP	17.18	17.17	13.10	21.10	1.50
	VOCs	98.98	74.50	4.00	2500.00	200.17

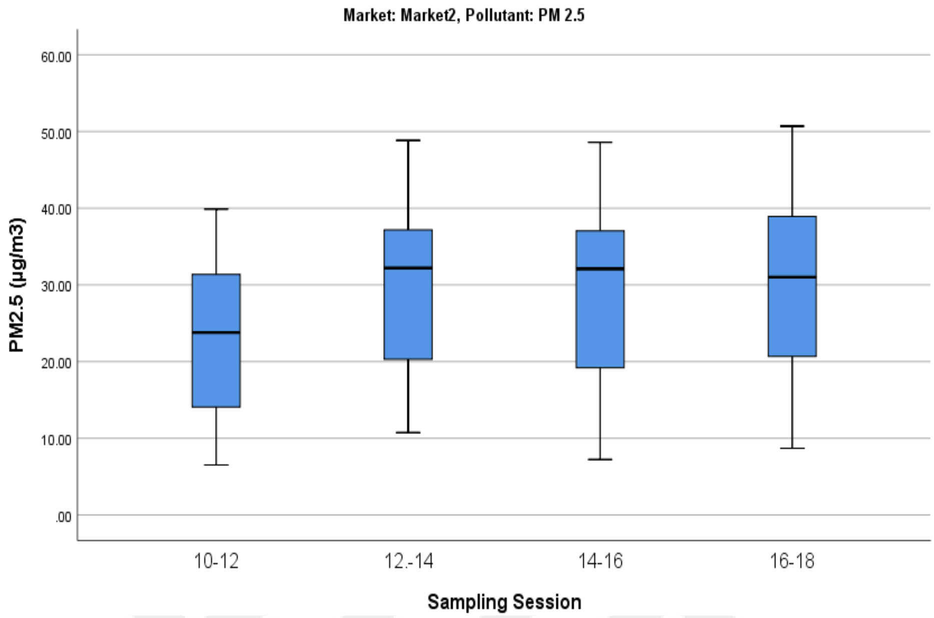

Figure 4.11. $PM_{2.5}$ Concentration by Sampling Session Market-2

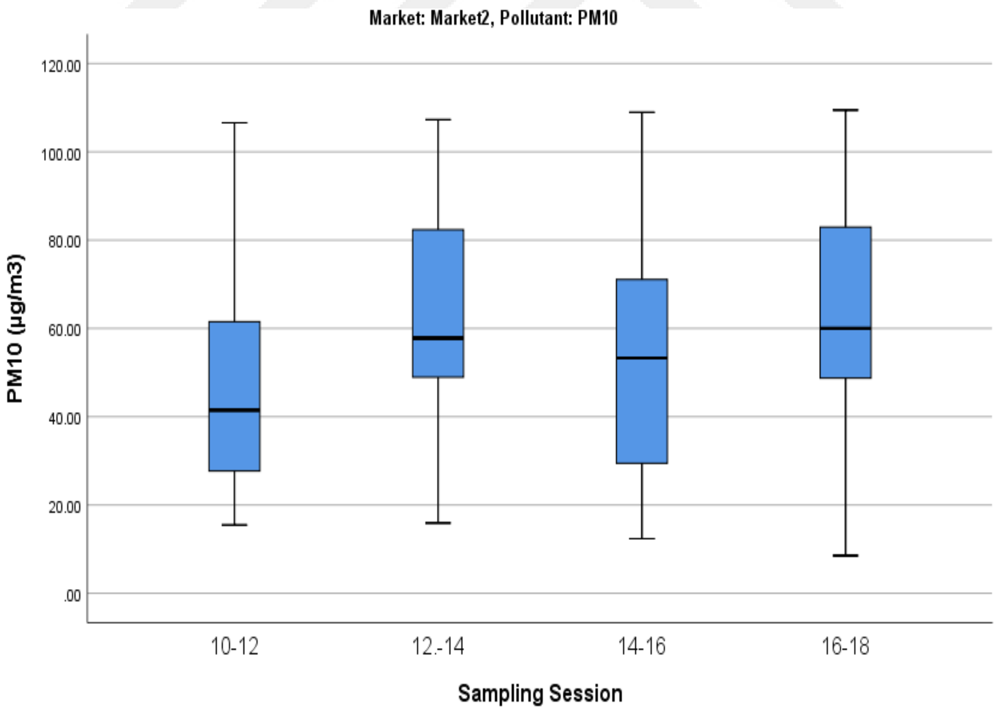

Figure 4.12. PM_{10} Concentration by Sampling Session Market-2

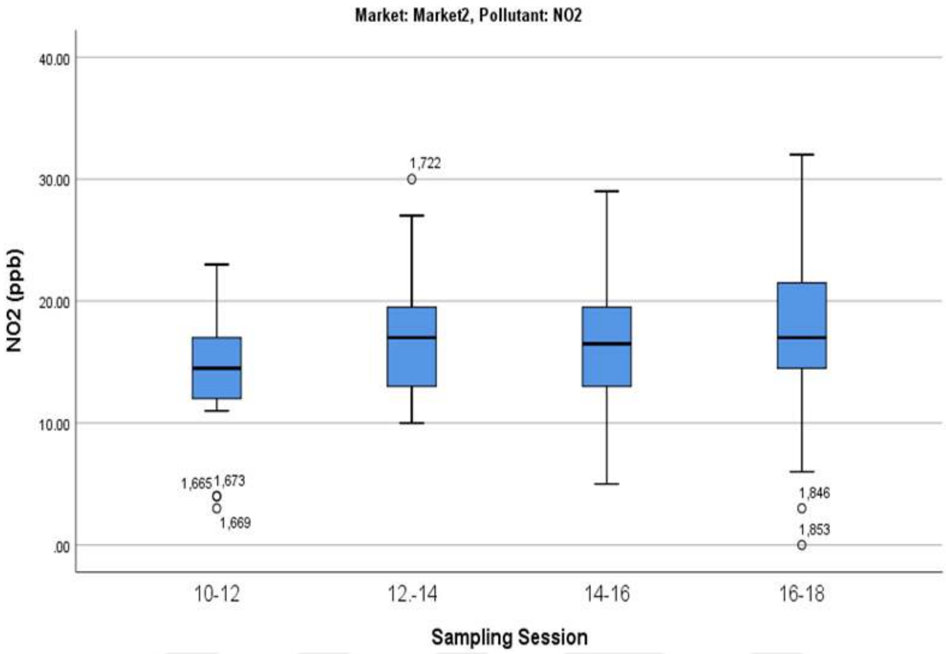

Figure 4.13. NO_2 Concentration by Sampling Session Market-2

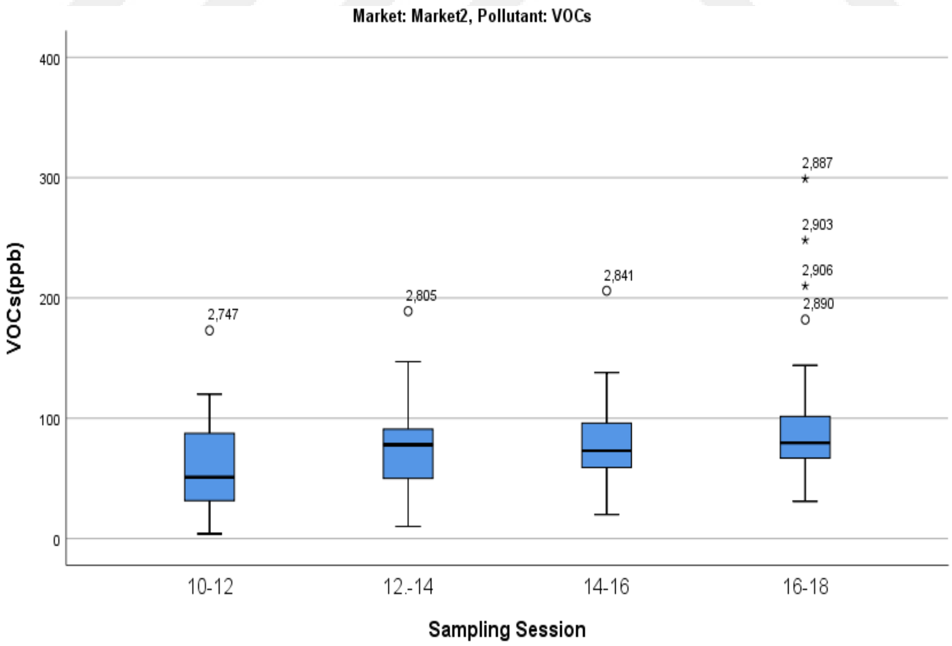

Figure 4.14. VOCs Concentration by Sampling Session Market-2

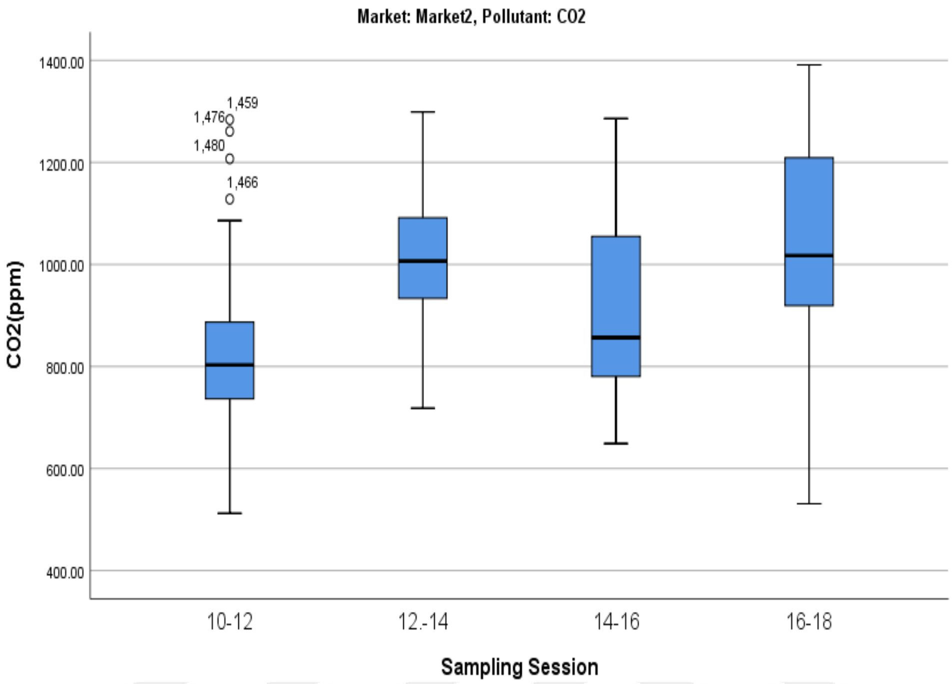

Figure 4.15. CO_2 Concentration by Sampling Session Market-2

4.1.2.4. Descriptive Statistics by Sampling Sessions by Market-3

For Market-3, temperature was between 14.20 and 21.50 °C, while relative humidity ranged between 29.67% and 79.20%.

Highest medians of NO_2 (19.00 ppb), $PM_{2.5}$ (26.91 µg/m3), PM_{10} (61.48 µg/m3) and VOCs (79.00 ppb) were noticed in 16-18 session, while lowest medians of CO_2 (627.00 ppm), $PM_{2.5}$ (13.80 µg/m3), PM_{10} (35.76 µg/m3) and VOCs (44.00 ppb) were noticed in 10-12 session.

Highest median of CO_2 (744.00 ppm) was in session 12-14, whereas lowest of NO_2 (14.00 ppb) was in the 14-16 session.

Table 4.5. Descriptive Statistics by Sampling Sessions by Market-3

Session		Mean	Median	Minimum	Maximum	Std. Deviation
10-12	CO_2	615.98	627.00	472.00	914.00	94.73
	NO_2	14.71	14.50	5.00	29.00	4.80
	$PM_{2.5}$	15.27	13.80	5.21	36.33	7.97
	PM_{10}	41.83	35.76	15.22	82.70	19.59
	RH%	56.03	58.07	31.03	78.28	11.92
	TEMP	16.45	16.30	14.20	18.80	1.16
	VOCs	53.29	44.00	15.00	185.00	31.84
12.-14	CO_2	753.48	744.00	504.00	1104.00	141.71
	NO_2	17.48	17.50	11.00	29.00	3.84
	$PM_{2.5}$	24.94	24.40	5.27	47.26	11.73
	PM_{10}	57.95	56.17	16.76	100.19	23.54
	RH%	53.93	55.35	30.40	79.20	11.20
	TEMP	16.88	16.85	14.40	21.50	1.43
	VOCs	85.10	76.00	11.00	487.00	70.52
14-16	CO_2	717.56	677.00	463.00	1283.00	156.17
	NO_2	16.13	14.00	3.00	30.00	5.84
	$PM_{2.5}$	20.09	17.89	5.47	47.62	12.73
	PM_{10}	46.79	44.47	9.54	106.44	25.10
	RH%	54.14	54.77	33.43	73.14	10.29
	TEMP	17.04	17.00	14.90	21.10	1.45
	VOCs	83.12	75.50	15.00	186.00	36.30
16-18	CO_2	749.04	717.67	483.00	1274.00	165.62
	NO_2	18.54	19.00	8.00	28.00	4.15
	$PM_{2.5}$	24.53	26.91	1.08	48.01	11.73
	PM_{10}	57.95	61.48	2.40	102.01	23.42
	RH%	54.27	56.69	29.67	76.57	10.62
	TEMP	17.12	16.85	14.70	21.00	1.53
	VOCs	92.52	79.00	15.00	898.00	117.73
Total (All Sessions)	CO_2	709.02	668.00	463.00	1283.00	151.71
	NO_2	16.72	17.00	3.00	30.00	4.90
	$PM_{2.5}$	21.21	19.64	1.08	48.01	11.78
	PM_{10}	51.13	51.91	2.40	106.44	23.90
	RH%	54.59	56.14	29.67	79.20	10.98
	TEMP	16.87	16.80	14.20	21.50	1.42
	VOCs	78.50	72.00	11.00	898.00	73.75

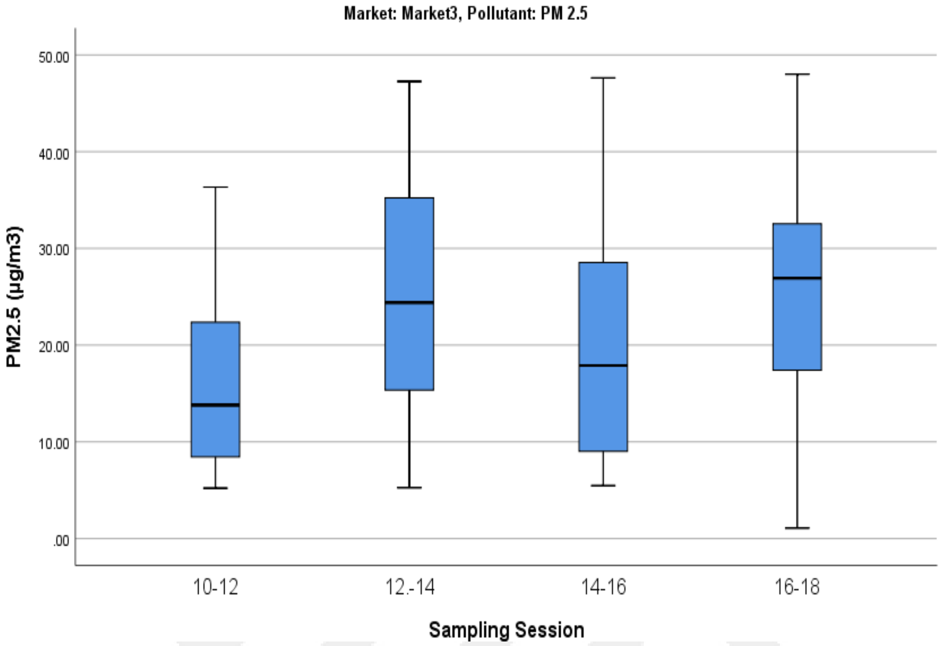

Figure 4.16. $PM_{2.5}$ Concentration by Sampling Session Market-3

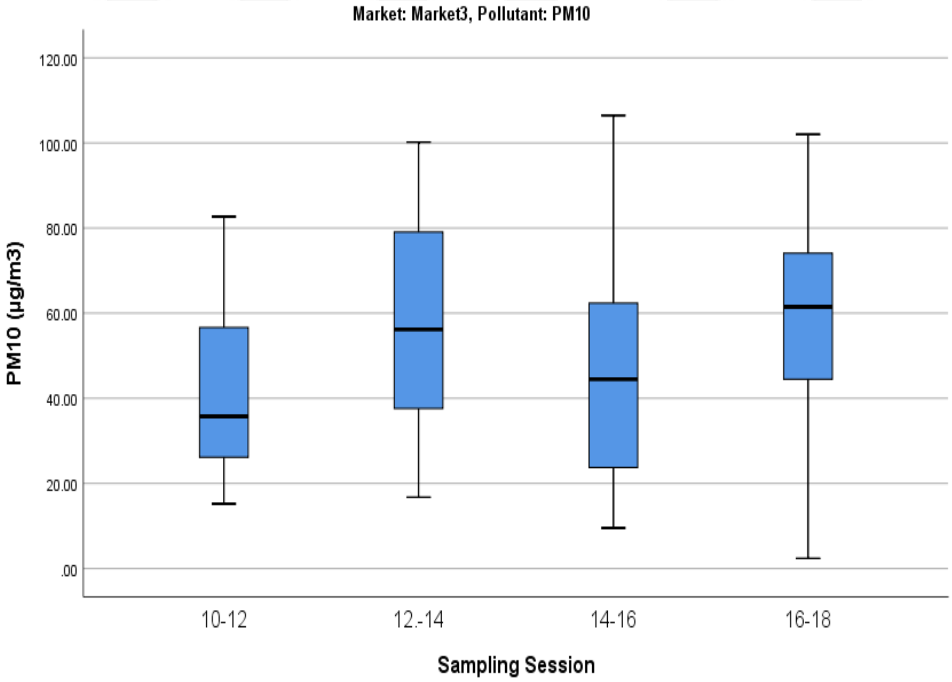

Figure 4.17. PM_{10} Concentration by Sampling Session Market-3

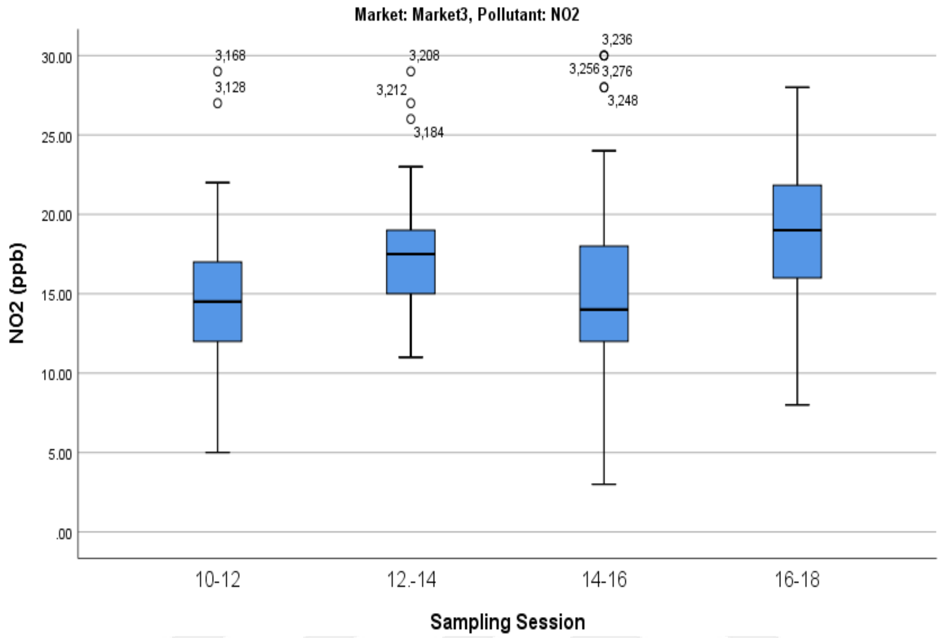

Figure 4.18. NO_2 Concentration by Sampling Session Market-3

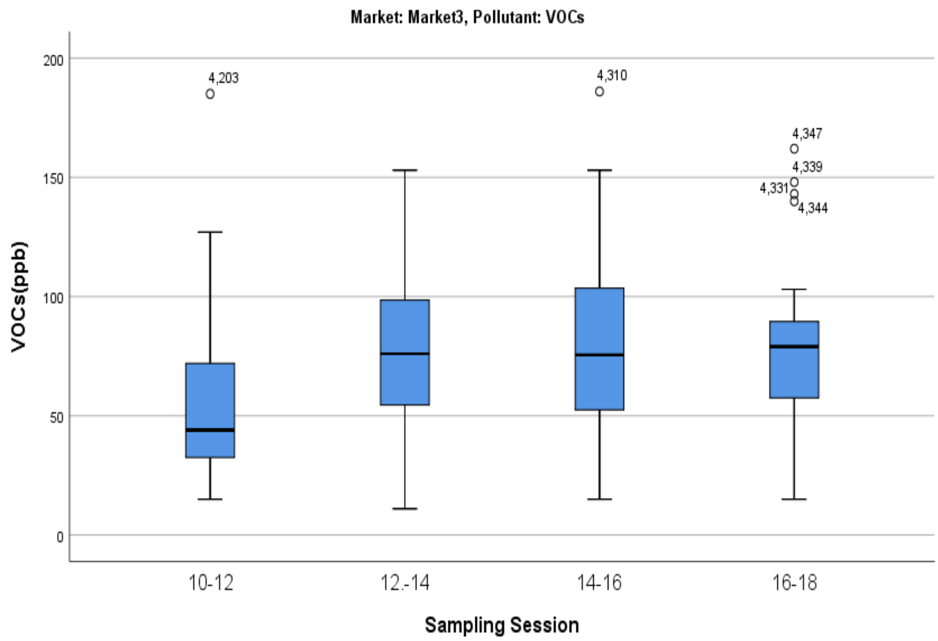

Figure 4.19. VOCs Concentration by Sampling Session Market-3

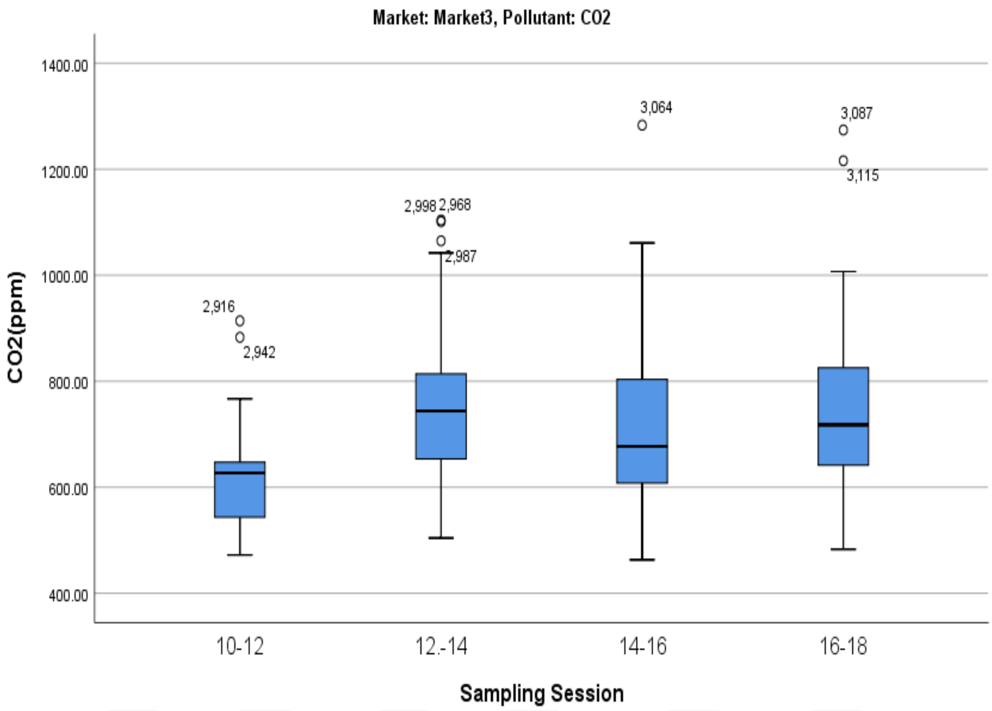

Figure 4.20. CO_2 Concentration by Sampling Session Market-3

4.1.2.5. Descriptive Statistics by Sampling Sessions by Market-4

For Market-4, temperature was between 16.30 and 22.60 °C, while relative humidity ranged between 29.38% and 68.43%.

Highest medians of NO_2 (18.00 ppb) and PM_{10} (50.99 µg/m3) were in 16-18 session, also highest CO_2 (686.50 ppm), $PM_{2.5}$ (17.48 µg/m3), and VOCs (83.00 ppb) were noticed in 12-14 sessions.

Lowest medians of CO_2 (579.00 ppm), NO_2 (13.50 ppb), $PM_{2.5}$ (9.43 µg/m3) and PM_{10} (30.82 µg/m3) were noticed in 10-12 session.

Table 4.6. Descriptive Statistics by Sampling Sessions by Market-4

Session		Mean	Median	Minimum	Maximum	Std. Deviation
10-12	CO_2	593.02	579.00	460.00	863.00	92.47
	NO_2	12.52	13.50	4.00	21.00	3.64
	$PM_{2.5}$	12.40	9.43	4.81	31.87	6.22
	PM_{10}	32.46	30.82	5.46	70.87	15.67
	RH%	48.03	49.22	22.43	68.43	10.65
	TEMP	19.33	19.50	16.30	21.10	1.08
	VOCs	50.71	40.50	16.00	150.00	29.59
12-14	CO_2	706.88	686.50	500.00	1007.00	127.00
	NO_2	16.77	17.00	5.00	27.00	4.59
	$PM_{2.5}$	17.94	17.48	5.63	37.24	7.72
	PM_{10}	50.32	50.48	13.43	103.86	21.51
	RH%	46.27	47.58	24.80	66.35	10.07
	TEMP	20.13	20.10	17.60	22.30	1.18
	VOCs	82.52	83.00	13.00	231.00	41.45
14-16	CO_2	701.62	664.50	490.00	1196.00	145.24
	NO_2	16.42	15.00	7.00	31.00	6.06
	$PM_{2.5}$	15.33	12.46	5.90	38.16	8.15
	PM_{10}	43.42	39.18	4.38	104.05	21.80
	RH%	45.41	46.01	20.38	67.06	10.54
	TEMP	20.22	20.10	17.80	22.60	1.07
	VOCs	76.79	81.50	18.00	149.00	29.93
16-18	CO_2	719.81	685.50	555.00	964.00	95.47
	NO_2	17.44	18.00	9.00	25.00	3.77
	$PM_{2.5}$	17.68	17.30	3.53	35.67	8.23
	PM_{10}	50.09	50.99	10.84	108.90	19.97
	RH%	45.53	47.07	22.47	67.28	10.29
	TEMP	20.29	20.30	17.80	22.30	1.06
	VOCs	84.22	79.67	3.00	320.00	48.71
Total (All Sessions)	CO_2	680.33	657.50	460.00	1196.00	126.97
	NO_2	15.79	15.00	4.00	31.00	4.97
	$PM_{2.5}$	15.84	15.13	3.53	38.16	7.89
	PM_{10}	44.07	43.64	4.38	108.90	21.04
	RH%	46.31	47.36	20.38	68.43	10.37
	TEMP	19.99	20.10	16.30	22.60	1.16
	VOCs	73.56	67.50	3.00	320.00	40.33

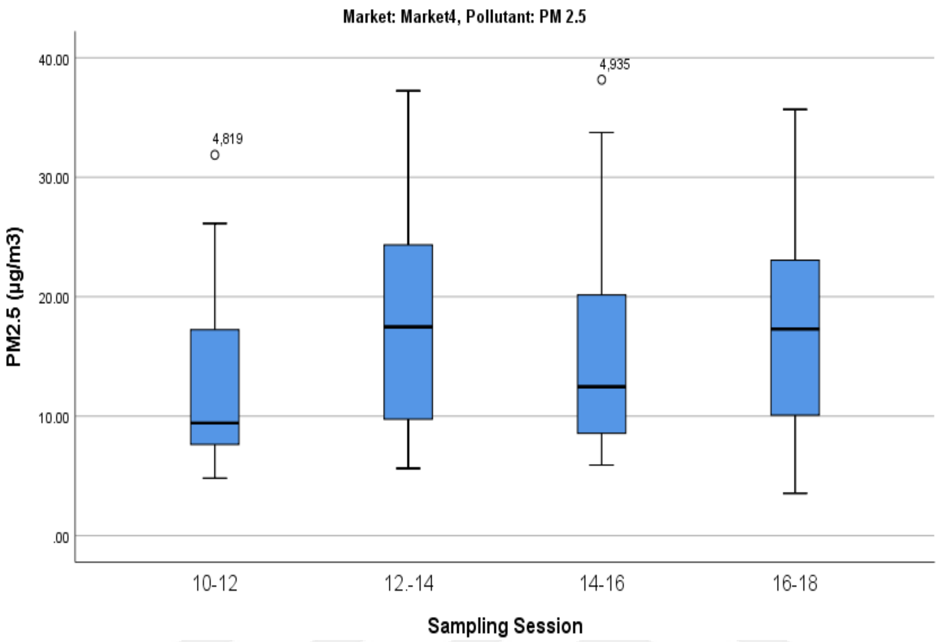

Figure 4.21. $PM_{2.5}$ Concentration by Sampling Session Market-4

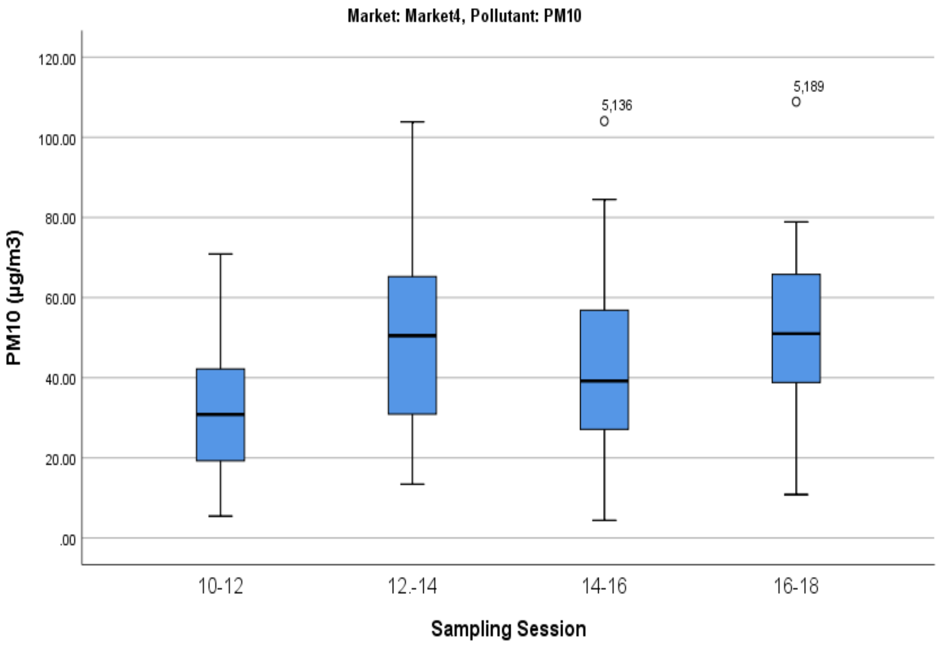

Figure 4.22. PM_{10} Concentration by Sampling Session Market-4

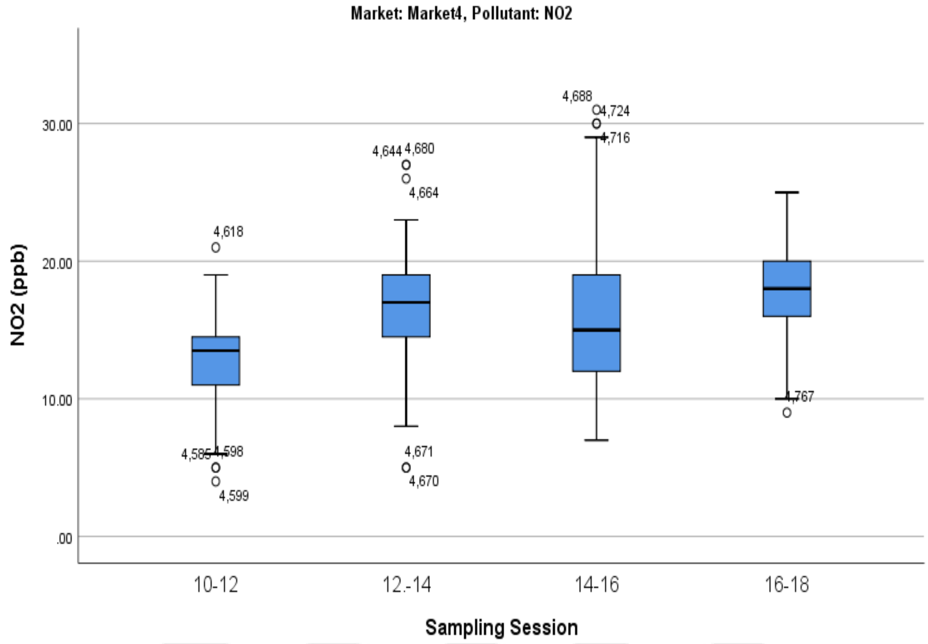

Figure 4.23. NO_2 Concentration by Sampling Session Market-4

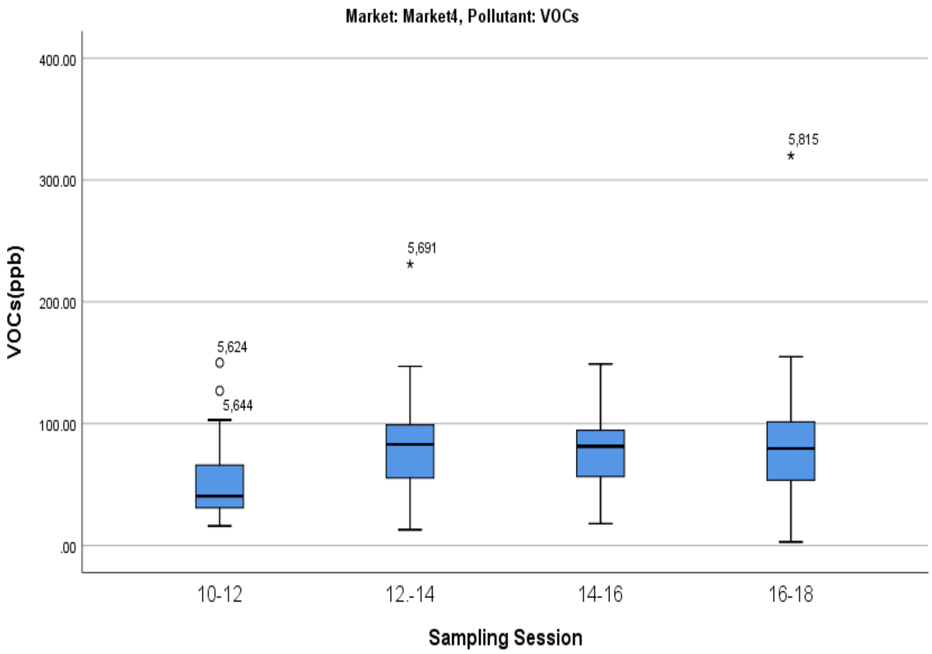

Figure 4.24. VOCs Concentration by Sampling Session Market-4

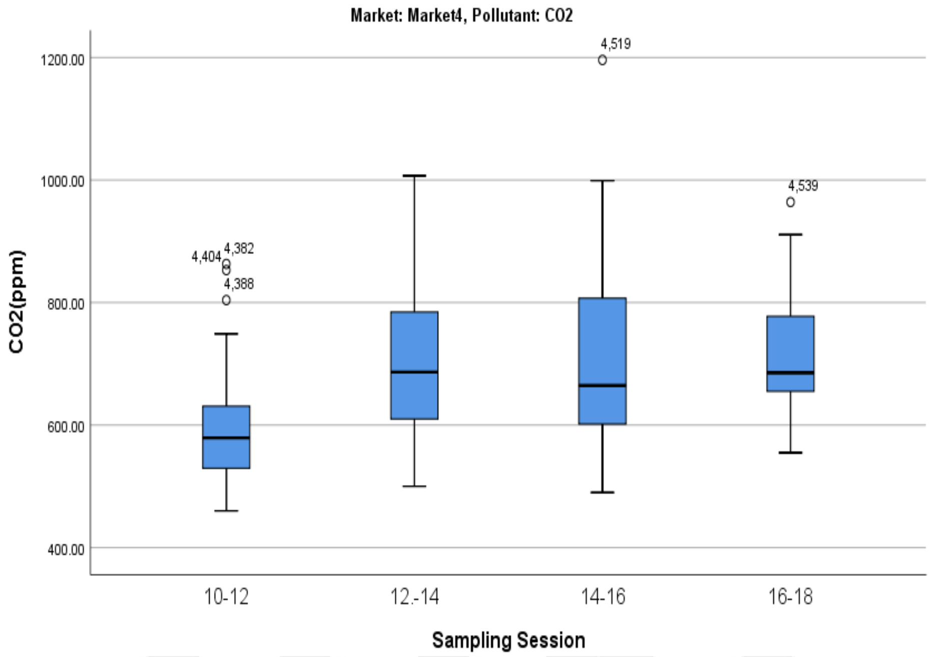

Figure 4.25. CO_2 Concentration By Sampling Session Market-4

4.1.3. Descriptive statistics All Samples by Weekday/Weekend

In weekdays, temperature was between 13.10 and 22.60 °C, while relative humidity ranged between 20.38% and 77.07%.

In Weekends temperature was between 14.20 and 21.80 °C, while relative humidity ranged between 26.93% and 86.53%.

Highest medians of all samples were noticed in Weekends compared to weekdays.

Table 4.7. Descriptive Statistics all Samples by Weekday/Weekend

		Mean	Median	Minimum	Maximum	Std. Deviation
Weekday	CO_2	761.99	717.50	460.00	1391.00	196.54
	NO_2	15.29	15.00	.00	37.00	4.98
	$PM_{2.5}$	20.75	19.16	1.08	50.70	11.24
	PM_{10}	46.19	45.30	2.40	109.45	21.93
	RH%	51.30	52.44	20.38	77.07	11.18
	TEMP	18.06	18.10	13.10	22.60	1.88
	VOCs	76.64	69.00	3.00	1181.00	73.23
Weekend	CO_2	854.31	826.00	476.00	1292.00	192.13
	NO_2	19.28	19.00	11.00	31.00	4.63
	$PM_{2.5}$	29.40	32.20	5.63	48.59	10.70
	PM_{10}	66.95	69.22	4.38	109.29	23.32
	RH%	52.02	53.54	26.93	86.53	12.40
	TEMP	17.95	17.90	14.20	21.80	1.75
	VOCs	100.65	82.17	17.00	2500.00	180.86
Total (All Days)	CO_2	785.07	754.00	460.00	1391.00	199.38
	NO_2	16.29	16.00	.00	37.00	5.19
	$PM_{2.5}$	22.91	21.82	1.08	50.70	11.71
	PM_{10}	51.38	51.05	2.40	109.45	24.02
	RH%	51.48	52.86	20.38	86.53	11.49
	TEMP	18.03	18.10	13.10	22.60	1.85
	VOCs	82.64	73.00	3.00	2500.00	110.80

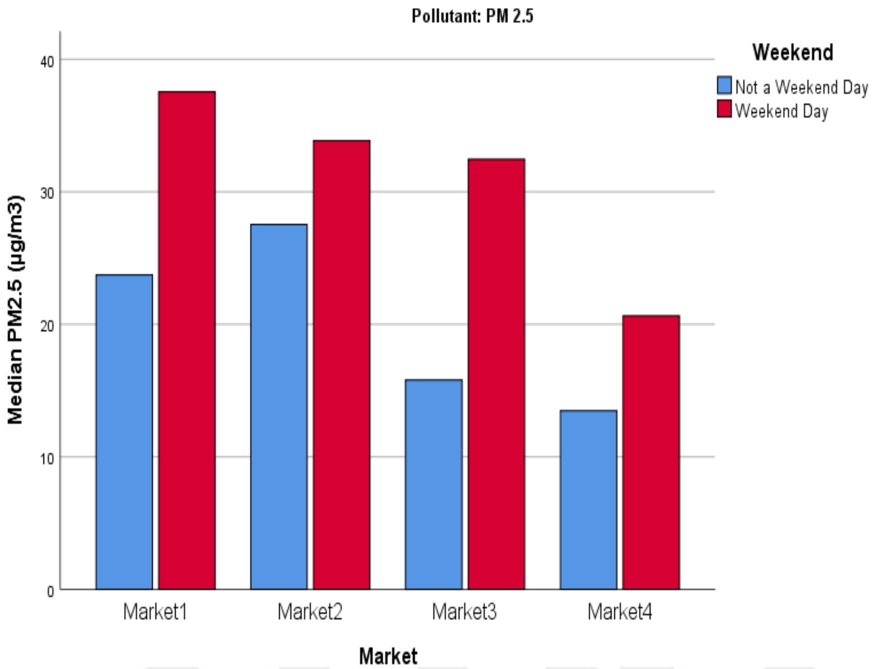

Figure 4.26. $PM_{2.5}$ Concentration by Weekend/Weekday All Marketplaces.

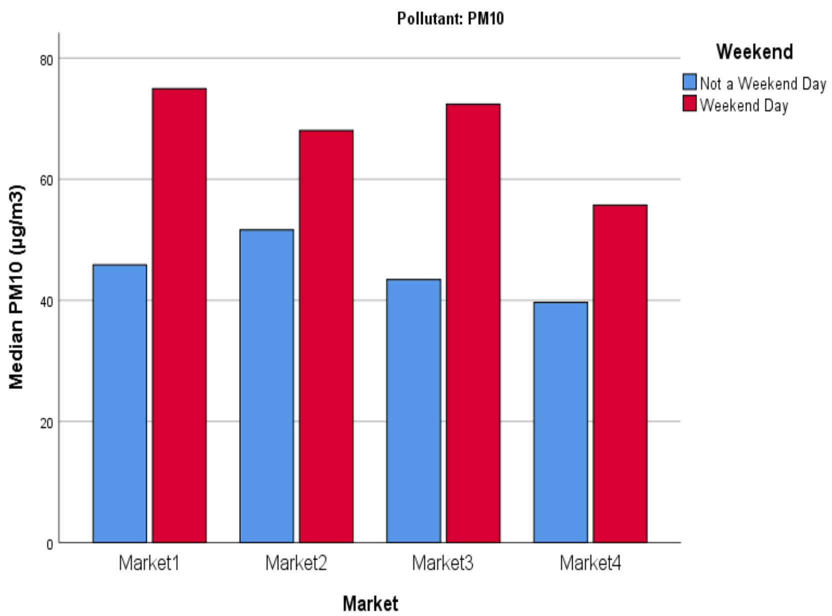

Figure 4.27. PM_{10} Concentration by Weekend/Weekday All Marketplaces.

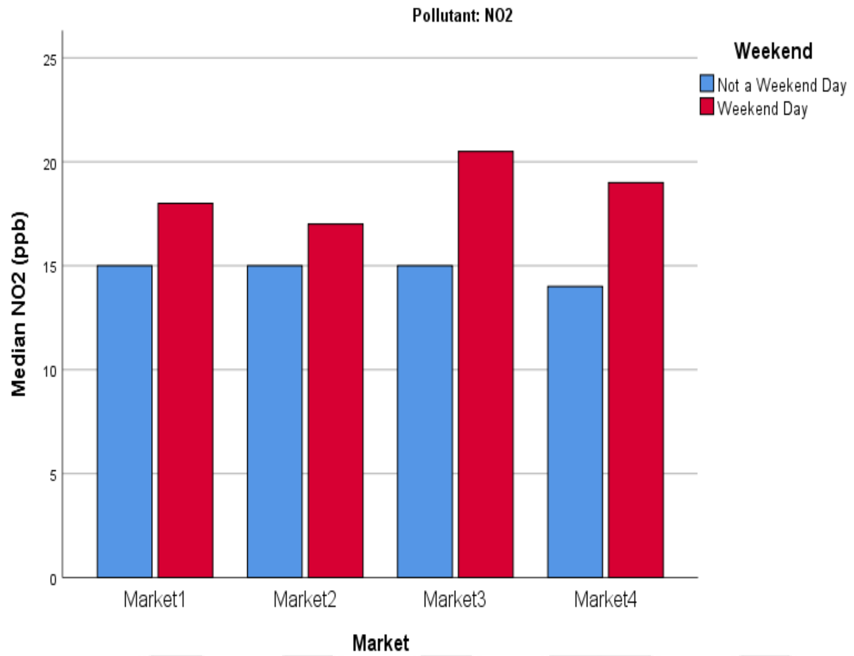

Figure 4.28. NO_2 Concentration by Weekend/Weekday All Marketplaces.

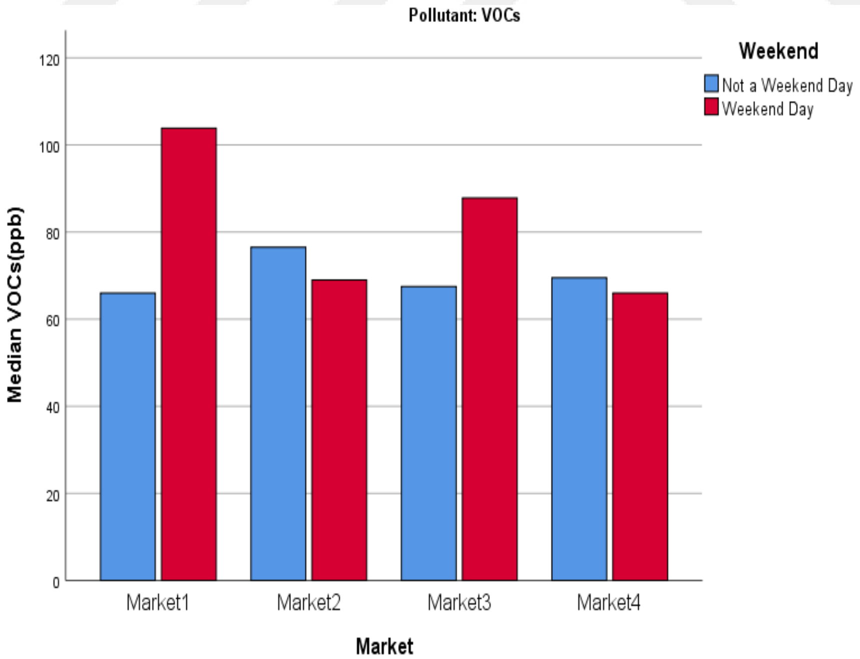

Figure 4.29. VOCs Concentration by Weekend/Weekday All Marketplaces.

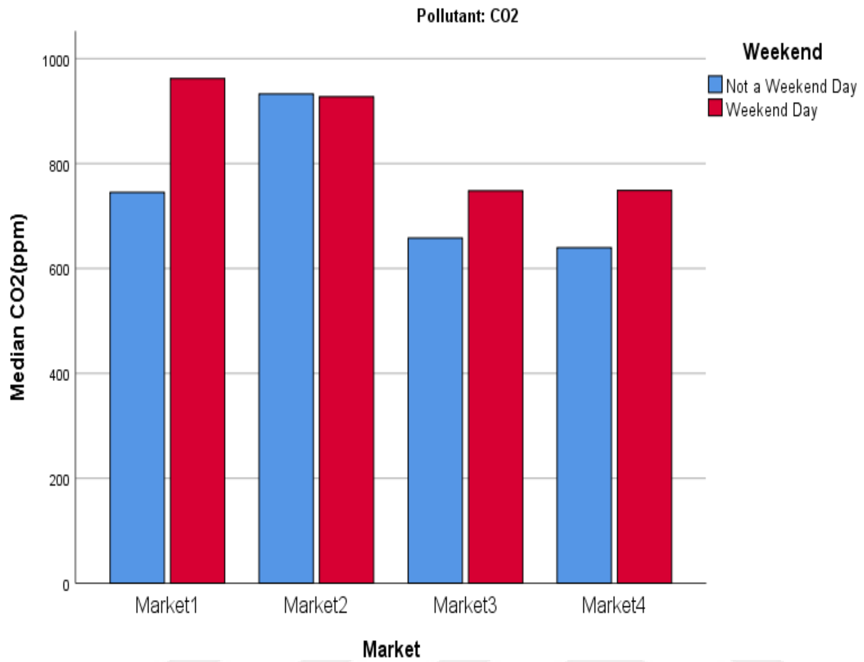

Figure 4.30. CO_2 Concentration by Weekend/Weekday All Marketplaces.

4.2. ANOVA

4.2.1. ANOVA by Marketplace

Table 4.8 shows the results of the ANOVA by marketpkace for all sampling sessions and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four marketplaces using all the sampling sessions, with a confidence level of 95%.

The table shows that for CO_2, $PM_{2.5}$ and PM_{10}, there is a statistically significant difference, all p-values are less than 0.05, which means the ratio of these three pollutants is not the same for all the marketplaces, at least two marketplaces have different ratio for CO_2, $PM_{2.5}$ and PM_{10}.

For NO_2 (0.314) and VOCs (0.094), the results are not statistically significant, and we cannot conclude that the ratio of NO_2 or VOCs is different across the marketplaces.

Table 4.8. ANOVA by Marketplace

Pollutant	F statistic	p-value
CO_2 (ppm)	102.234	**.000**
NO_2 (ppb)	1.186	.314
$PM_{2.5}$ (µg/m3)	56.080	**.000**
PM_{10} (µg/m3)	10.393	**.000**
VOCs(ppb)	2.134	.094

Bold = Statistically significant difference

Table 4.9 below presents the Tukey post-hoc analysis by marketplace including all sampling sessions and for the five pollutants. We use this type of analysis usually when the ANOVA test gives a statistically significant result, which is the case for CO_2, $PM_{2.5}$ and PM_{10} by marketplace, and for the pollutants who do not give a statistically significant results, the Tukey post-hoc analysis is not necessary, it will show that all the marketplaces are the same as we already conclude from ANOVA table.

From the table, we can conclude that for CO_2, the only pair with no statistically significant difference is Market-3 vs Market-4 (p-value = 0.317), all the other pairs are statistically significan different. For $PM_{2.5}$, the only pair with no statistically significant difference is Market-1 vs Market-2 (p-value= 0.47), all the other pairs are statistically significant different. For PM_{10}, we have three pairs with statistically significant difference, Market-1 vs Market-4, Market-2 vs Market-4, Market-3 vs Market-4.

Table 4.9. Tukey by Marketplace

		P-value				
		CO_2 (ppm)	NO_2 (ppb)	$PM_{2.5}$ (µg/m3)	PM_{10} (µg/m3)	VOCs(ppb)
Market-1	Market-2	**.000**	.972	.470	.863	.277
	Market-3	**.000**	.755	**.000**	.532	1.000
	Market-4	**.000**	.838	**.000**	**.000**	.947
Market-2	Market-3	**.000**	.945	**.000**	.145	.234
	Market-4	**.000**	.582	**.000**	**.000**	.089
Market-3	Market-4	.317	.262	**.000**	**.013**	.968

Bold = Statistically significant difference

4.2.2. ANOVA by Sampling Session

Table 4.10 shows the results of the ANOVA by sampling session for all marketplaces and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four time periods using all the marketplaces, with a confidence level of 95%.

The table shows that all the five pollutants CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs have p-values less than 0.05, which means the ratio of these five pollutants is not the same in all sampling sessions, at least two sessions have different ratio for CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs.

Table 4.10. ANOVA by Sampling Session

Pollutant	F statistic	p-value
CO_2 (ppm)	34.883	**.000**
NO_2 (ppb)	25.398	**.000**
$PM_{2.5}$ (µg/m3)	22.844	**.000**
PM_{10} (µg/m3)	29.609	**.000**
VOCs(ppb)	3.612	**.013**

Bold = Statistically significant difference

Table 4.11 presents the Tukey post-hoc analysis by sampling session including all marketplaces and for the five pollutants.

From the table, we can conclude that for CO_2, the only pair with no statistically significant difference is session 2 (12-14) vs session 4 (16-18), all the other pairs are statistically different. For NO_2, there are two pairs with no statistically significant difference: session 2 (12-14) vs session 3 (14-16), and session 2 vs session 4, all the other pairs are statistically different. For $PM_{2.5}$, there are two pairs with no statistically significant difference: session 2 vs session 4, and session 3 vs session 4, all the other pairs are statistically significant different. For PM_{10}, we have only one pair with no statistically significant difference, session 2 vs session 4. For VOCs, we have three pairs with statistically significant difference: session 2 vs session 3, session 2 vs session 4 and session 3 vs session 4.

Table 4.11**.** Tukey by Sampling Session

		P-value				
		CO_2 (ppm)	**NO_2 (ppb)**	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**	**VOCs(ppb)**
10-12	12-14	**.000**	**.000**	**.000**	**.000**	.077
	14-16	**.000**	**.000**	**.000**	**.000**	**.038**
	16-18	**.000**	**.000**	**.000**	**.000**	**.020**
12-14	14-16	**.005**	.996	**.050**	**.007**	.993
	16-18	.623	.052	1.000	.979	.962
14-16	16-18	**.000**	**.028**	.060	**.002**	.996

Bold = Statistically significant difference

4.2.3. ANOVA by Sampling Session Market-1

Table 4.12 shows the results of the ANOVA by sampling session for market-1 and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four time periods, for market-1, with a confidence level of 95%.

The table shows that all the four pollutants CO_2, NO_2, $PM_{2.5}$ and PM_{10} have p-values less than 0.05, which means the ratio of these four pollutants is not the same in all sampling sessions, at least two sessions have different ratio for CO_2, NO_2, $PM_{2.5}$

and PM_{10}. For VOCs, there is no statistically significant difference between the four sampling sessions in market-1 (p-value = 0.177).

Table 4.12. ANOVA by Sampling Session Market-1

Pollutant	F statistic	p-value
CO_2 (ppm)	14.306	**.000**
NO_2 (ppb)	6.749	**.000**
$PM_{2.5}$ (µg/m3)	9.165	**.000**
PM_{10} (µg/m3)	10.363	**.000**
VOCs(ppb)	1.657	.177

Bold = Statistically significant difference

Table 4.13 presents Tukey post-hoc analysis by sampling session for market-1. From the table, we can conclude that for CO_2, three pairs have a statistically significant difference: session 1 vs session2, session 1 vs session 4 and session 3 vs session 4. For NO_2, there are three pairs with statistically significant difference: session 1 vs session 2, and session 1 vs session 3, and session 2 vs session 3. For $PM_{2.5}$, also three pairs have a statistically significant difference: session 1 vs session2, session 1 vs session 3 and session 1 vs session 4. For PM_{10}, three pairs have a statistically significant difference: session 1 vs session2, session 1 vs session 3 and session 1 vs session 4. For VOCs, all the pairs are not statistically significant different as we already conclude from the previous ANOVA table.

Table 4.13. Tukey by Sampling Session Market-1

		P-value				
		CO_2 (ppm)	**NO_2 (ppb)**	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**	**VOCs(ppb)**
10-12	12-14	**.000**	.514	**.000**	**.000**	.177
	14-16	.150	**.008**	**.008**	**.001**	.829
	16-18	**.000**	**.000**	**.000**	**.000**	.336
12-14	14-16	.075	.253	.568	.968	.635
	16-18	.428	**.037**	1.000	.871	.984
14-16	16-18	**.001**	.827	.546	.614	.841

Bold = Statistically significant difference

4.2.4. ANOVA by Sampling Session Market-2

Table 4.14 shows the results of the ANOVA by sampling session for market-2 and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four time periods, for market-2, with a confidence level of 95%.

The table shows that all the four pollutants CO_2, NO_2, $PM_{2.5}$ and PM_{10} have p-values less than 0.05, same result as for marke-2, which means the ratio of these four pollutants is not the same in all sampling sessions, at least two sessions have different ratio for CO_2, NO_2, $PM_{2.5}$ and PM_{10}. For VOCs, there is no statistically significant difference between the four sampling sessions in market-2 (p-value = 0.58). (same conclusion as market-1)

Table 4.14. ANOVA by Sampling Session Market-2

Pollutant	F statistic	p-value
CO_2 (ppm)	17.140	.000
NO_2 (ppb)	4.608	.004
$PM_{2.5}$ (µg/m3)	5.156	.002
PM_{10} (µg/m3)	6.559	.000
VOCs(ppb)	.656	.580

Bold = Statistically significant difference

Table 4.15 below presents the Tukey post-hoc analysis by sampling session for market-2.

From the table, we can conclude that for CO_2, four pairs have a statistically significant difference: session 1 vs session2, session 1 vs session 4, session 3 vs session 4 (all the three are the same as for market-1), and session 2 vs session3. For NO_2, there are two pairs with statistically significant difference: session 1 vs session 2, and session 1 vs session 4. For $PM_{2.5}$, three pairs have a statistically significant difference: session 1 vs session2, session 1 vs session 3 and session 1 vs session 4. For PM_{10}, two pairs have a statistically significant difference: session 1 vs session 2 session 1 vs session 4. For VOCs, all the pairs are not statistically significant different as we already conclude from the previous ANOVA table.

Table 4.15. Tukey by Sampling Session Market-2

		P-value				
		CO_2 (ppm)	NO_2 (ppb)	$PM_{2.5}$ (µg/m3)	PM_{10} (µg/m3)	VOCs(ppb)
10-12	12-14	**.000**	**.019**	**.006**	**.001**	.931
	14-16	.198	.095	**.033**	.268	.539
	16-18	**.000**	**.004**	**.004**	**.001**	.760
12-14	14-16	**.003**	.929	.948	.225	.883
	16-18	.882	.962	.999	1.000	.981
14-16	16-18	**.000**	.691	.907	.196	.984

Bold = Statistically significant difference

4.2.5. ANOVA by Sampling Session Market-3

Table 4.16 shows the results of the ANOVA by sampling session for market-3 and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four time periods, for market-3, with a confidence level of 95%.

The table shows that all the five pollutants CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs have p-values less than 0.05, which means the ratio of these five pollutants is not the same in all sampling sessions, at least two sessions have different ratio for CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs.

Table 4.16. ANOVA by Sampling Session Market-3

Pollutant	F statistic	p-value
CO_2 (ppm)	10.552	**.000**
NO_2 (ppb)	6.424	**.000**
$PM_{2.5}$ (µg/m3)	8.506	**.000**
PM_{10} (µg/m3)	6.502	**.000**
VOCs(ppb)	2.938	**.034**

Bold = Statistically significant difference

Table 4.17 presents Tukey post-hoc analysis by sampling session for market-3. From the table, we can conclude that for CO_2, three pairs have a statistically significant difference: session 1 vs session 2, session 1 vs session 3 and session 1 vs session 4. For NO_2, there are also three pairs with statistically significant difference: session 1 vs session 2, and session 1 vs session 4, and session 3 vs session 4. For $PM_{2.5}$, only two pairs have a statistically significant difference: session 1 vs session 2 and session 1 vs session 4. For PM_{10}, two pairs have a statistically significant difference: session 1 vs session2 and session 1 vs session 4. For VOCs, only one pair has a statistically significant difference: session 1 vs session 4.

Table 4.17. Tukey by Sampling Session Market-3

		P-value				
		CO_2 (ppm)	NO_2 (ppb)	$PM_{2.5}$ (µg/m3)	PM_{10} (µg/m3)	VOCs(ppb)
10-12	12-14	**.000**	**.016**	**.000**	**.002**	.119
	14-16	**.002**	.417	.128	.689	.160
	16-18	**.000**	**.000**	**.000**	**.002**	**.033**
12-14	14-16	.571	.467	.123	.067	.999
	16-18	.999	.664	.998	1.000	.954
14-16	16-18	.672	**.049**	.183	.067	.912

Bold = Statistically significant difference

4.2.6. ANOVA by Sampling Session Market-4

Table 4.18 shows the results of the ANOVA by sampling session for market-4 and for each pollutant individually. The hypothesis to test was, for each pollutant, is there a statistically significant difference in the mean between the four time periods, for market-4, with a confidence level of 95%.

The table shows that all the five pollutants CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs have p-values less than 0.05, which means the ratio of these five pollutants is not the same in all sampling sessions, at least two sessions have different ratio for CO_2, NO_2, $PM_{2.5}$, PM_{10} and VOCs. (same as market-3)

Table 4.18. ANOVA by Sampling Session Market-4

Pollutant	F statistic	p-value
CO_2 (ppm)	13.062	**.000**
NO_2 (ppb)	12.028	**.000**
$PM_{2.5}$ (µg/m3)	5.930	**.001**
PM_{10} (µg/m3)	9.223	**.000**
VOCs(ppb)	8.590	**.000**

Bold = Statistically significant difference

Table 4.19 presents Tukey post-hoc analysis by sampling session for market-4. From the table, we can conclude that for CO_2, NO_2, PM_{10} and VOCs, session 1 is statistically significant different from the other three. For $PM_{2.5}$, session 1 vs session 2 and session 1 vs session 4 are the only statistically significant pairs.

Table 4.19. Tukey by Sampling Session Market-4

		P-value				
		CO_2 (ppm)	**NO_2 (ppb)**	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**	**VOCs(ppb)**
10-12	12-14	**.000**	**.000**	**.002**	**.000**	**.000**
	14-16	**.000**	**.000**	.206	**.028**	**.003**
	16-18	**.000**	**.000**	**.003**	**.000**	**.000**
12-14	14-16	.996	.981	.304	.290	.871
	16-18	.943	.879	.998	1.000	.996
14-16	16-18	.858	.674	.399	.321	.756

Bold = Statistically significant difference

5. CONCLUSION

Indoor air quality has a crucial role in health maintenance. Understanding the detrimental impacts of indoor air pollution will enable us to take the necessary preventive actions to minimize any health concerns.

During the Winter of 2020, data were collected at four marketplaces over a fifty-two-day period. For comparative purposes, $PM_{2.5}$, PM_{10}, NO_2, CO_2, VOCs, temperature, and relative humidity were monitored for four sessions each day. The data analysis revealed substantial differences in markets, weekdays/weekends, and sampling sessions.

Maximum temperature readings were within ASHRAE winter guidelines. However, minimum temperature readings were slightly below ASHRAE winter guidelines, which may cause moderate discomfort to persons who prefer a warmer indoor atmosphere in the winter.

Relative humidity levels varied considerably, sometimes exceeding ASHRAE standards. The median value, on the other hand, was within ASHRAE recommendations.

Market-4 had the lowest $PM_{2.5}$ during the day, Although Market-1 had the highest $PM_{2.5}$ median in lunchtime (12:00-14:00), Market-2 had the highest $PM_{2.5}$ medians during all other time periods.

All $PM_{2.5}$ medians were within the ASHARE recommended 8-hour average, which corresponded to the time period covered by the measurements.

When the PM_{10} medians of all marketplaces were compared to the ASHRAE recommendations, it was discovered that, though marketplaces medians varied, none exceeded the requirements.

NO_2 and VOCs, the statistic results are not statistically significant, and we cannot conclude that the ratio of NO_2 or VOCs is different across the marketplaces.

On the other hand, all NO_2 tests, including the maximum, were under the recommended limits for indoor NO_2 concentrations.

VOCs measurements varied greatly; this is owing to the nature of VOCs, especially now that all marketplaces in Turkey are required to have hand sanitizers at the entry following COVID-19 regulations, and the majority of consumers sanitized their hands when entering.

Highest CO_2 concentrations were noticed at Market-2, having the poorest CO_2 levels, followed by Market-1 and Market-3, while the lowest concentrations were found at Market-4.

Due to the fact that not all organizations consider CO_2 to be a pollutant, there are no clear indoor CO_2 concentration standards, we can be certain that observed quantities have a negative influence on indoor air quality.

A statistically significant difference between markets was seen for PM levels ($PM_{2.5}$, $p<0.000$); PM_{10}, $p<0.000$), CO_2 ($p<0.000$), NO_2 ($p>0.314$) and VOCs ($p>0.094$). The null hypothesis "there will be no statistically significant difference between sampling locations' 52-days median airborne particle ($PM_{2.5}$, PM_{10}, CO_2, NO_2 and VOCs) concentrations" is partially rejected.

Generally, Market-2 had the highest concentrations of all selected parameters, this may be due to the fact that Market-2 sells more affordable products, causing higher customer traffic.

Whereas Market-4 had the lowest concentrations, as observed during the sessions, Market-4 had better ventilation systems, and the doors were regularly left open to ventilate the air, in addition to the strict rules the marketplace employees enforced regarding the number of individuals allowed at the same time.

A statistically significant difference between Sampling Sessions was seen for all Parameters $PM_{2.5}$ ($p=0.000$), PM_{10} ($p=0.000$), CO_2 ($p=0.000$), NO_2 ($p=0.000$) and VOCs ($p=0.013$) at all markets.The null hypothesis "there will be no statistically significant difference between sampling sessions in 52-days median airborne particle ($PM_{2.5}$, PM_{10}, CO_2, NO_2 and VOCs) concentrations indoors" is rejected.

All marketplaces had a spike in sample's concentrations during lunch break (12:00-14:00) and closing hours (16:00-18-00), this is due to the increased number of customers during that period, where customers tend to visit the marketplace before the lockdown hours.

Weekends tend to have higher concentrations of all samples. This could be because some people were unable to shop during the week due to early lockdown hours, forcing them to shop on weekends. Another possibility is that because individuals were only permitted to go outside to buy groceries during the lockdown, individuals visited marketplaces simply to be outdoors, resulting in heavier traffic than on weekdays.

This research shows that there are differences in $PM_{2.5}$, PM_{10}, NO_2, VOCs, CO_2, temperature and humidity levels between marketplaces, day of the week, and time of day.

Lastly, this research study provided pilot data of how Indoor Air Quality. It is advised that comprehensive sampling be conducted numerous times during the day, varying between weekdays and weekends, as this study demonstrated that these periods often have greater levels of pollutants and other indoor air quality indicators.

Future research might examine the impacts of reduced working hours (due to lockdown in this study) and normal working hours on indoor air quality.

Future studies could also investigate a variety of marketplace settings, such as locations with refrigerators, cashiers, sections with DIY and cleaning products.

It is advisable to investigate the relationship between various building and occupant variables, such as flooring or walls.

Lastly, future research should compare indoor and outdoor concentrations, and conduct sampling during multiple seasons of the year.

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