STATISTICAL ANALYSIS OF THE EFFECT OF METEOROLOGICAL PARAMETERS ON PM10

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ABSTRACT

STATISTICAL ANALYSIS OF THE EFFECT OF METEOROLOGICAL PARAMETERS ON PM10

Air pollution is a serious threat where the pollutants in the air in solid, liquid and gaseous states reach levels that would harm the natural balance of the environment and the lives of vital organisms. Especially in industrialized cities, in addition to the effects of urbanization, physical environment characteristics may also play a role in the formation of environmental problems. Therefore, it is of high importance to understand the characteristics of the natural environment in the studies on air quality, in order for urban spaces to be livable areas.

In this study, the correlations between PM10 pollutant data and certain meteorological parameters that were obtained from 3 stations in İzmir province were statistically evaluated. PM10 data was studied according to pre-pandemic, mid-pandemic and post-pandemic periods between 2017–2021. Meteorological data was gathered for a twelve-month period between February 2021 and January 2022 and its effect on PM10 data for the same period was analyzed. In the statistical analysis that was performed via Minitab software, hourly average data of PM10 was the dependent variable; temperature, relative humidity, and wind speed and direction were the independent variables. In the analysis that Pairwise Pearson Correlation Coefficient (r) was used, the most significant correlation was found to be between relative humidity and wind speed.

ÖZET

METEOROLOJİK PARAMETRELERİN PM10 ÜZERİNDEKİ ETKİSİNİN İSTATİSTİKSEL ANALİZİ

Hava kirliliği; katı, sıvı ve gaz halinde havada bulunan kirleticilerin, çevrenin doğal dengesine ve canlıların yaşamına zarar verecek düzeylere ulaşmasıdır. Özellikle sanayinin geliştiği kentlerde gelişen çevre sorunlarının şekillenmesinde, yerleşmeden kaynaklı etkilerin yanı sıra fiziki ortam özelliklerinin de etkisi olabilmektedir. Bu nedenle yerleşmelerin yaşanabilir alanlar olması için hava kalitesi incelemelerinde, doğal ortam özelliklerinin anlaşılması önem kazanmıştır.

Bu çalışmada; İzmir İlindeki üç istasyona ait partikül madde 10 (PM10) kirleticisinin verileri ile bazı meteorolojik parametreler arasındaki ilişkiler istatistiksel olarak incelenmiştir. 2017-2021 yıllarına ait PM10 verileri pandemi öncesi, pandemi dönemi ve pandemi sonrası dönemler düşünülerek incelenmiştir. Meteorolojik veriler ise 2021 Şubat ile 2022 Ocak arasındaki 12 ay için ölçülmüş ve aynı dönemdeki PM10 verileri üzerindeki etkileri analiz edilmiştir. Minitab yazılımı kullanılarak yapılan istatistiksel incelemede saatlik ortalamaları alınan PM10 verisi bağımlı değişken; sıcaklık, bağıl nem, rüzgâr hızı ve yönü verileri bağımsız değişkenler olarak ele alınmıştır. Pairwise Pearson Correlation Coefficient (r) kullanılarak yapılan analizde en anlamlı sonuç bağıl nem ile rüzgar hızı arasında gözlemlenmiştir.

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CHAPTER 1

INTRODUCTION

Population rise and industrial development have led to excessive consumption of the Earth's resources. The rapid consumption of natural resources has already reached an irreversible level by the beginning of the 21st century. In particular, environmental disasters that have occurred in recent years have caused people to adapt to the expected negativities and include the concept of adaptation in future scenarios, as well as to create solutions to the problems. Securing our future is seen to be closely connected to sustainable development. Sustainability entered into people's lives as "sustainable development" with the Brundtland Report titled "Our Common Future" prepared by the UN World Commission on Environment and Development in 1987. While meeting the needs of people today, it guarantees a clean environment, a developed economy, and a good quality of life for generations, in which the needs of future generations are not ignored. Sustainable development can also be defined as personal well-being that does not decrease over time (Adams, 2001).

Air quality in cities can change directly or indirectly due to climate change, natural disasters such as forest fires, anthropogenic sources such as traffic, industry or domestic heating, atmospheric (airflow direction and intensity) and meteorological (temperature, humidity, wind speed and direction) variables, and topographic characteristics of a region. In addition to these, the growth rate, and spatial development direction and form of cities also affect air quality (Stone et al., 2007; Lu and Liu, 2015). Air pollution can be caused by point sources such as factories, thermal power plants, residences, and landfills, as well as non-point, mobile (e.g. motor vehicle traffic) sources. Therefore, many urban planning components such as urban form and texture, population density, locations of polluting lands, traffic volume and street continuity are essential in terms of air quality.

Interest in renewable and inexhaustible energy sources such as solar, wind, hydraulic, geothermal, biomass, biogas, and wave energy has increased significantly in recent years. As renewable energy sources are less damaging to the environment, do not produce greenhouse gasses, and can be generated domestically, they are seen as the preferable choice. Renewable energy sources play an important role in preventing air pollution. As well as environmental engineers, air pollution studies also draw the attention of energy systems engineers for future generations. In particular, the search for alternative solutions to anthropogenic sources that cause air pollution is at the core of the studies of energy systems engineering.

Air pollution problems develop under the influence of meteorological variables. Pollutants released from a source into the atmosphere are carried to the exposed areas by various air movements. Movement of the pollutant in the atmosphere occurs both horizontally and vertically. It is important to address meteorological factors as well when examining the causes of air pollution (Oğuz, 2020).

The thesis is a part of the URBAN GreenUP Project which is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 730426. The URBAN GreenUP Project, aims to obtain a tailored methodology to support the co-development of Renaturing Urban Plans, focused on decreasing air pollution, climate change mitigation and adaptation as well as efficient water management, and to effectively assist in the implementation of Nature-Based Solutions (NBSs) in urban areas.

The aim of this thesis study carried out within the scope of the above-mentioned project is to focus on the issue of air pollution. İzmir Province, which is the study area of the project, is the third largest city in Turkiye. Therefore, population, traffic and construction density is high. Considering these characteristics of İzmir province, it is aimed to examine PM10, an air pollutant originating from human activities such as fossil fuel use, industrial facilities, agricultural activities, transportation, etc. in this study. Meteorological parameters are the important factors on dispersion and dilution of air pollutants (Mayer, 1999). Therefore, the relationship between PM10 and meteorological parameters was also analyzed. The PM10 data were obtained from air quality monitoring stations in Bayraklı, Karşıyaka and Çiğli, the central districts of İzmir Province. For the measurement of meteorological data, Sasalı Natural Life Park in Çiğli and Vilayetler Evi Hotel in Bostanlı were chosen as the study area. 1-year meteorological data between February 2021 and January 2022 were measured and the relationship of PM10 pollutant with meteorological parameters was determined by statistical analysis.

CHAPTER 2

AIR POLLUTION

Before defining or explaining air pollution, it is very important to know what air is and what it contains. In general terms, air, like other basic components, is necessary for humans and general living organisms. In the gas mass called the atmosphere, there is a layer where living things can survive within the composition of the gasses in the air, and this layer is called the 'troposphere' in the literature. If we look at the content of pure air, several noble gasses, especially nitrogen and oxygen, are present in certain ratios. These ratios are approximately 78% nitrogen, 21% oxygen, 1% carbon dioxide and other noble gasses (Hennig et al., 2016).

Various pollutants are released into the air environment in line with the industrialization as a result of human activities and urbanization, such as dust, smoke, steam, coarse or fine particles, gasses, etc. Such pollutants have negative effects on living beings, commercial or personal belongings. Air environment, being not a stable but a dynamic structure, can transform from a local issue to a global danger (Gurjar and Ojha, 2016). For this reason, it is necessary to carry out studies to be able to make realistic and logical evaluations on the effect of air pollution on living beings' health (Hennig et al., 2016).

Along with industrialization, use of low-quality fuel, heavy traffic and exhaust gas emissions, inadequacy of green areas can be counted among the factors that cause air pollution (Grsic et al., 2014). In addition, as mentioned before, the air mass which has a dynamic structure can play a role in the transport or mixing of air pollutants by meteorological factors such as temperature, wind direction and speed, and relative humidity (Filonchyk and Yan, 2019).

Carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), ozone (O_3), hydrogen sulfide (H_2S), hydrogen fluoride (HF), volatile organic compounds (VOC) are among the present or occurred pollutants in the air. As particulate matter, PM2.5 and PM10 are the pollutants whose diameters are 2.5 mm and less than 10 mm, respectively. The health effect of these pollutants on living life is related to the size of the particles during the exposition. Possible sources of air pollutants are displayed in Table 2.1 (EPA, 2021). Pollutant concentrations may vary based on the meteorologic factors (Ahmad et al., 2013).

Table 2.1. Air pollutants and their sources.
(Source: EPA, 2021)

Pollutants	**Sources**
Particulate matter (PM)	Volcanic eruptions, forest fires, incomplete combustion, traffic, electric power-plants, construction, and agriculture activities
Sulfur oxides (SO_x)	Combustion of sulfur contented materials, electric power-plants, combustion of fossil fuel
Carbon monoxide (CO)	Cigarette, incomplete combustion, traffic emissions, solid waste storage facility and production facilities
Nitrogen oxides (NO_x)	Fossil fuel combustion, industrial and electric power-plants, exhaust emission
Ozone (O_3)	These are the secondary pollutants that occur between the nitrogen oxides and pollutants as a result of the photochemical reactions in the atmosphere.

2.1. Air Pollutants

There are numerous air pollutants in the atmosphere whereas the sources continuously are in transformation. The pollutants can be categorized as primary and secondary such that this categorization could be also named as classification by origin. The primary pollutants are stated as the sources are directly pervaded to the atmosphere and analyzed in five main groups. These are CO, SO_x, NO_x, hydrocarbon (HC) and PM. The secondary pollutants are the ones that occur based on components such as natural, sulfur, organic, nitrogen and photochemical reactions like O_3 (Gustafson, 2009; Godish at al., 2014). It is also possible to categorize the air pollutants according to human activities, chemical compositions and physical forms. In the human activities classification, the pollutants based on the sources, in the chemical composition classification they are categorized once more based on being organic or inorganic and as last in physical classification the pollutants are categorized as gas or particles (Wark et al., 1998).

The biggest factor of air pollution is human activities. The effects of the air pollution that is occurred based on human activities may change territorially (Kliengchuay et al., 2018). Cities are on the forefront where the effects of human activities are dense. The areas where there is an industry, buildings and central business fields are usually sensitive in terms of air pollution in the cities. In case of not taking due precautions, in the process of industrial production, in the heating of the houses and in the daily activities of the central business fields air pollution takes place to a considerable extent (Cohen et al., 2005).

2.1.1. Sulfur Oxide (SO_x)

The most harmful form of the SO_x that threatens the environment and the human health is sulfur dioxide (SO_2). It is a common gas where it is colorless, unburnable, nonexplosive and has toxic, bad and strong odor in high concentrations. It may react with the other components and turn into sulfur trioxide (SO_3) and sulfate in the atmosphere. In addition to that, if SO_3 occurs in the rainy environment, it may cause acid rains as sulfuric acid (H_2SO_4) by uniting with the drops in the air. The sources of SO_2 are generally human-made. The combustion of fossil fuels has the highest share with 80% (Kozlowski, 1980; Manisalidis et al., 2020).

2.1.2. Nitrogen Oxide (NO_x)

NO_x is one of the most important air pollutants caused by exhaust gasses and fossil fuel combustion whereas forest fires, lightning and similar natural sources could be another sources. Nitrogen monoxide (NO) is one of the types of NO_x types which is a noble gas that has medium toxicity to the environment. Even NO reduces the oxygen-carrying capacity like CO, since it stays on the air in the concentration less than 1 ppm, it is thought that not harmful. However, by being oxidized NO transforms to NO_2 becomes harmful for the health (Olsson and Benner, 1999; Steinfeld, 1998; Tiwary and Williams, 2018; Wark et al., 1998).

2.1.3. Carbon Monoxide (CO)

CO is a toxic gas which is colorless and scentless, and has a density that is less than air, and it occurs as a result of deficient or insufficient combustion. Not being detected easily makes CO pretty threatening in terms of health (Weinstock, 1969; Weinstock and Niki, 1972). Atmospheric CO is the main resource of the hydroxyl radicals. CO has a significant effect in the constitution of the greenhouse gasses. Its sources are generally the same as the SO_2. It is an air pollutant that could be called as “criteria" also for the indoor air quality. Unaired gas oil and water heaters, leaking chimneys and ovens are the sources of the CO for the indoor air environment (EPA, 2018).

2.1.4. Ozone (O_3)

O_3 is a gas that has three oxygen atoms and is classified as a secondary air pollutant as a result of the photochemical processes. It has a strong oxidation and reactive characteristics. O_3 concentration in the atmosphere may be affected by the solar radiation density and temperature gradients. Due to that, it may vary in different seasons at different times. If an increase is observed in O_3 concentration, this change is centered around the increase of the volatile organic emissions during the day and the decrease of the NO_x emissions (Ying et al., 2009).

2.1.5. Particulate Matters (PM2.5, PM10)

According to the Environmental Protection Agency (EPA), a PM is defined as a blend of the particles and droplets in the air that consists of the components such as organic compounds, metals, acids, soil and dust. It may be composed of in many different natural or artificial ways, and it is complicated since it has many chemical matters in its structure (Levy et al., 2007).

Different natural and anthropogenic emission sources, windy soil dust, sea and biogenic aerosols, road traffic and land vehicles, constant burning process, industrial and construction processes and the combustion of agricultural waste contribute to the PM concentration in the atmosphere (El-Fadel and Massoud, 2000). The smaller the diameter of the particle, the longer it hangs in the air and more it harms. The atmospheric PM whose aerodynamic diameter <10 μm (PM10) or <2,5 μm (PM2.5) is an important source of concern for public health. These particles consist of the chemical and the biological components of the atmospheric microorganisms. Limit values of PM2.5 and PM10 pollutants in the regulations of Turkiye, European Union (EU), World Health Organization (WHO) and The United States of America (USA) are given in Table 2.2 (EPA, 2021).

Table 2.2. Limit values of PM air pollutant in the regulations.
(Source: EPA, 2021)

	Air Pollutant	Time Unit	Average Limit Value (μg/m^3)
TURKIYE	PM2.5	Ave. for 24 hours Annual ave.	25 -
	PM10	Ave. for 24 hours annual ave.	50 40
EU	PM2.5	Ave. for 24 hours annual ave.	25 25
	PM10	Ave. for 24 hours annual ave.	50 40
WHO	PM2.5	Ave. for 24 hours annual ave.	25 10
	PM10	Ave. for 24 hours annual ave.	50 20
USA	PM2.5	Ave. for 24 hours annual ave.	35 12
	PM10	Ave. for 24 hours annual ave.	50 25

2.2. Air Quality Index (AQI)

The Air Quality Index (AQI), used to track the concentrations of air pollutants, is an important and comprehensive indicator of air quality and is used by government agencies to predict how polluted the air is currently or how polluted the air will be. The AQI value allows people who do not have technical knowledge on air quality, to have information about air quality easily, and it is a guide in order to prevent exposure to air pollution in their daily activities (Genc et al., 2010).

2.3. Air Pollution in Turkiye

In Turkiye, the data gathered by observations and studies show that the concentrations of air pollutants are above the acceptable limit values by the AQI, especially in winter. At the same time, it is stated that improving the air quality in medium- and small-sized cities is more difficult than improving the air quality in developed megacities. The aim for protecting or regulating air quality is to reduce pollution that affects the environment or human health to acceptable levels. The AQI is a formation that monitors and evaluates air quality in some cities, established by researchers after the 1970s in Turkiye. In the 1990s, a system based on continuous monitoring and observations was set in larger cities (Elbir et al., 2000).

First National Air Quality Monitoring Station was installed in Samsun in 2015. With the station installed in İzmir in 2016, the number of stations connected to the National Air Quality Monitoring Network started to increase. In İzmir, there are 23 air quality monitoring stations to measure the air pollutant concentrations originating from the fuels used for industry, heating systems and traffic. Currently, there are 340 air quality monitoring stations in Turkiye as given in Figure 2.1 (http://sim.csb.gov.tr).

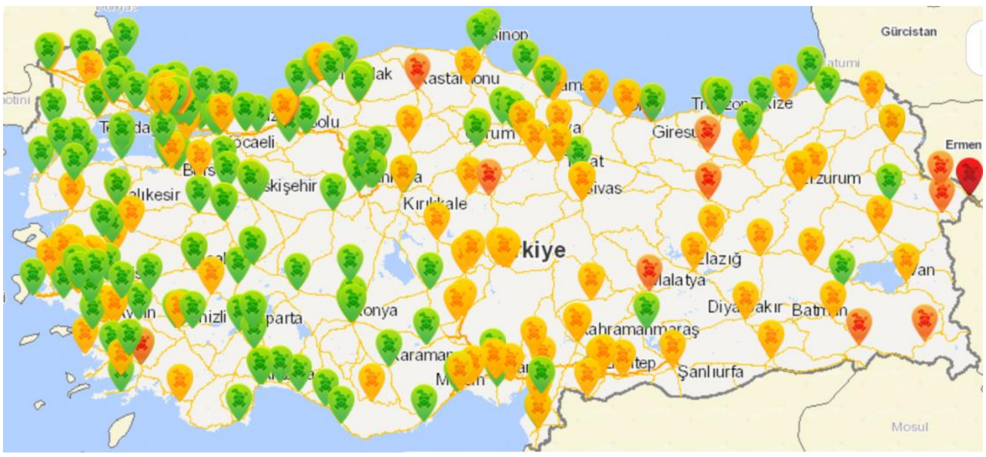

Figure 2.1. The location of the air quality monitoring stations.
(Source: http://sim.csb.gov.tr.)

The data collected from air quality monitoring stations are used to determine AQI. The AQI scale and the colors that are used for the air quality level in Turkiye is displayed in the Table 2.3 while the AQI levels of the underlying pollutants to this index is displayed in Table 2.4. The level 1 in Table 2.4 represents high-quality (very clean) air whereas the level 6 represents very bad quality (very dirty) air. These values are not found based on the mathematical calculations but only state the classification of the pollutant concentrations that are measured in the air by their effects. The main benchmark in this classification is the pollutant that has the highest AQI is taken as a basis among the other measured pollutants. In other words, AQI is stated according to the pollutant that is measured in the level that creates pollution (Varol et al., 2021).

Table 2.3. AQI scales and related colors.
(Source: Du and Varde, 2016)

AQI Levels	Description of Air Quality
1. Light green	Very good
2. Green	Good
3. Dark green	Satisfactory
4. Yellow	Moderate
5. Orange	Unhealthy for sensitive groups
6. Red	Unhealthy

Table 2.4. EPA AQI standards for health issues
(Source: EPA, 2021).

Levels of Concern	AQI	Description
Good	0-50	Little or no risk.
Moderate	51-100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Sensitive	101-150	Members of sensitive groups may experience health effects.
Unhealthy	151-200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Bad	201-300	Emergency conditions may occur.
Harmful	301-500	Health alert: The risk of health effects is increased for everyone.

The most important sources of pollution in Turkiye are urbanization and industrial production. In general perspective, even though the levels of the SO_x and NO_x are high, the PM is the most significant pollutant. The higher the AQI index the higher the air pollution.

Countries have constituted the AQI by being subjected to their own country's quality standards. Limit values in Turkiye are shown in Table 2.5.

Table 2.5. The indicated pollutants in the AQI and index concentrations. (Source:http://www.havaizleme.gov.tr)

Air Quality Index	SO_2	NO_2	CO	O_3	PM10
	Average for 1 hour	Average for 1 hour	Average for 8 hours	Average for 8 hours	Average for 24 hours
	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
1 (very good)	0-100	0-100	0-5500	0-120	0-50
2 (good)	101-250	101-200	5501-10000	121-160	51-100
3 (satisfactory)	251-500	201-500	10001-16000	161-180	101-260
4 (moderate)	501-850	501-1000	16001-24000	181-240	261-400
5 (poor)	851-1100	1001-2000	24001-32000	241-700	401-520
6 (very poor)	>1101	>2001	>32001	>701	>521

Figure 2.2 shows the air quality data of PM10 in 2020. Annual PM10 average in 97.7% (171 stations) of 175 stations in Turkiye in 2020 was above the limit value of WHO. When examining at the legal limit values in Turkiye, annual average of PM10 data exceeded national limits in 45 of 72 provinces. In terms of PM10 average in 2020, only Bitlis and Hakkari did not exceed the limit values recommended by WHO. In addition, in 83 (66.9%) of 124 stations, 24-hour PM10 levels were measured above 50 µg/m^3, which is stated in the legislation as not to be exceeded more than 35 days during the year (Right to Clean Air Platform, 2021).

In Turkiye, the Environmental Law (No:2872) that entered in force by promulgation on August 9th, 1983, constitutes the fundamental of the carried studies within the scope of air quality management. By this law, in accordance with the foreseen aim and principles in the related articles, the Air Quality Protection Regulation (AQPR) has been constituted. The AQPR (No:19269) that had been entered in force by promulgation on November 2nd, 1986, was repealed by the new by-laws where many of its articles afterwards promulgated in the same direction.

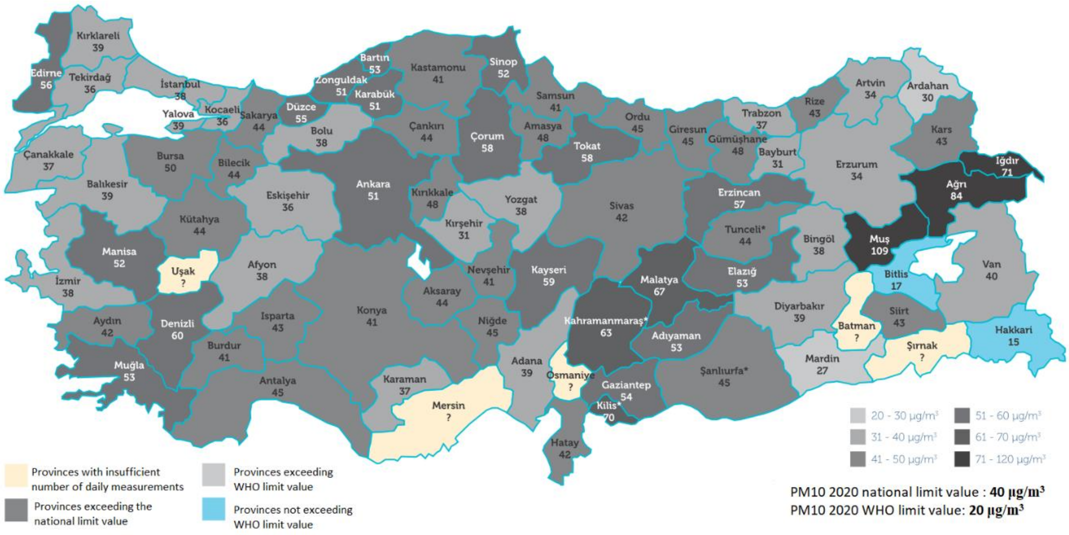

Figure 2.2. PM10 average data for provinces of Turkiye in 2020.
(Source: Right to Clean Air Platform, 2021)

The articles of the AQPR about the air pollution emissions were constituted based on two different regulations as industrial heating and domestic heating. For industrial facilities, Industrial Based Air Pollution Control Regulation (EBAPCR) has been entered in force on October 7th, 2004, with a number of 25606. In 2006, this regulation is replaced with Industrial Facilities Based Air Pollution Control Regulation (EFBAPCR). The Heating Based Air Pollution Control Regulation and Air Quality Assessment and Management Regulation (AQAMR) were entered into force on January 13th, 2005 and June 6th, 2008, respectively.

2.4. Air Quality Management

Air quality management is the whole of the detection and improvement work that aims for keeping the level of the emission that is given directly to the atmosphere as it does not harm the human and environmental health or taking due precautions to decrease it to this level (Büke at al., 2016). Since air pollution represents a global problem, one of the fundamental aims of the global efforts is reducing the air pollution levels according to the instructions of WHO and temporary targets (Gelles et al., 2020).

Compilation of the trustworthy quantitative emission data, in other words improvement of the emission inventory is a fundamental tool that is used in environmental policies. Countries find this kind of database useful due to the following reasons:

1.Elaboration of the probability for the realistic national emission reduce,

2.The distribution of the air pollutant emissions and the identification of the atmospheric transformation and convection mechanisms,

3.The evaluation of the effect of the transboundary pollution on to the national air pollution,

4.The improvements of the emission control scenarios for the areas that has high pollution concentration.

The Netherlands, Germany and Sweden are among the leading countries in Europe that have a long history in developing emission data (Lübkert and Tilly, 1989). The quantification of the chemical emissions that is given to the atmosphere is a fundamental step for the transformation of the pollutants in the atmosphere and the creation of the emission control policies (Kawashiwa et al., 2020).

2.5. Meteorologic Factors

The meteorological parameters are also important for the emerging of the air pollution as far as the polluting emissions.

2.5.1. The Effect of Wind

The most effective meteorological factor on the horizontal movement of the pollutants is the wind. The pollutants that are available in the atmosphere are mostly affected by the predominant wind direction, its frequency, and its force.

The horizontal movements of the wind are determined by the speed of the wind. The speed of the wind plays an important role in the deduction of the air pollution. High winds enable the decrease of the concentration during the downtick of the pollutants by separating them. At the same time for the winds being high causes the air to become turbulent and along with the constitution of an eddy, it is provided for the pollutants to be blended in the same proportion of the air (Ahrens, 2009).

The emission of the pollutants in the vertical direction occurs based on the ascent of the heated air which is in touch with the ground. The heated air mass has a lower pressure compared to the cold weather molecules that overruns itself and it rises along with the lifting force of the environment. During this rise the mass of the lifted air decreases. The temperature of the lifted air parcel decreases 1°C ideally in every 100 meter in the dry air. It increases in the descending air parcel (https://mgm.gov.tr).

2.5.2. The Effect of Temperature

The other important meteorological factor that affects the air pollution is temperature. The air pollution and the temperature are inversely proportional. The pollution increases as the temperature decreases. The increase in the use of fossil fuels due to heating in the winter months is created this inverse relationship.

2.5.3. The Effect of Relative Humidity

The humidity that exists in the atmosphere causes fog formation by becoming dense as a result of the decrease of the air temperature.

As the amount of the humidity increases in the atmosphere, the pollutants are spread later than expected and the inversion is constituted in an easier way. While the temperature change is 1°C/100 m in dry air, it is 0,65°C/100 m in humid air. In addition to inversion, the most harmful air pollution problems emerge along with fogs. The most important 3 cases that is caused by the water particles inside of the air could be summarized as;

- Fogs convert the SO_3 in the air into the sulphuric acid (H_2SO_4),
- The fogs that are descent to valley, decrease the effect of the sunlights to the ground and based on this by being delayed in terms of the heating of the valley, the inversion layer that occurs during the night stays long time on the valley. As a result of this the pollutants do not depart from that environment,
- The humidity in the air affects the speed change of the temperature by the height and therefore affects the stability of the atmospheric phenomena.

The humidity in the air brings rain by getting dense causes clearing the air. The rain drops take the pollutants along by catching them. This situation is called as “washing” of the air (https://mgm.gov.tr).

CHAPTER 3

LITERATURE REVIEW

In the literature, there are many studies on air pollutants, especially PM10 and SO_2, which are the most impactful pollutants. The factors that cause the formation of pollutants have been the basis for air pollution studies. However, meteorological factors, which have an important role in the transport, distribution and change of pollution, have also been the starting point of many of these studies.

In Çolak's study (1998), the relationships between air pollution (SO_2 and smoke) data and meteorological factors were examined by using SO_2 and smoke values collected from five stations, as well as meteorological factors. As a result, it was determined that there is a negative relationship between air pollution data and temperature and wind speed, and a positive relationship with pressure.

In the statistical study published by Demirci and Çuhadaroğlu (2020), research was conducted on the relationship of air pollutants such as SO_2 and PM with the wind direction in the city center of Trabzon. This study showed that for the period between November 1994 and December 1997, air pollutants were only slightly affected by the wind blowing from the northeast direction.

Başar et al. (2005) included air pollution (SO_2 and PM10) data and meteorological data measured between 1997-2003 in Aydın province in their analysis. The results indicated that long- and short-term limit values were not exceeded, and no difference was found in terms of SO_2 and PM concentrations over the years. Increase in air pollution data caused by meteorological conditions in the winter months was detected.

One of the studies on the evaluation of data on air pollution was published by Köse et al. (2006). In this study, the relationship between meteorological parameters and the formation of some air pollutants in Kütahya during the winter season was examined. The statistical relationship between PM and SO_2 air pollutants and meteorological factors between 1991-2001 was examined.

One of the studies on the evaluation of data on air pollution was published by Köse et al. (2006). In this study, the relationship between meteorological parameters and the formation of some air pollutants in Kütahya during the winter season was examined. The statistical relationship between PM and SO2 air pollutants and meteorological factors between 1991-2001 was examined.

In the study published by Çelik and Kadı (2007), the relationship of wind speed, relative humidity and temperature with SO_2 and PM concentration was examined with 24-hour continuous measurements from 1998 to 2001 in Karabük. The relationship between air pollution and meteorological factors was analyzed statistically.

In Çiçek et al. (2004), the data from the Sıhhiye air quality monitoring station located in the city center of Ankara was evaluated based on limit values of national and WHO. In the study, the data for the period between November 2001 and April 2002 was used. The relationship between the elements causing air pollution and climate elements such as temperature, wind speed and humidity were analyzed using the SPSS program. According to the results obtained by multiple regression analysis, it was determined that there was a moderate relationship between SO_2, PM10, NO, NO_2, CO and climate elements, especially in March.

Demir et al., in 2010, attempted to estimate atmospheric pollution by using Artificial Neural Networks (ANN). 1-year meteorological and PM10 datasets obtained from the Sarıyer-Bahçeköy station in Istanbul were used in the study and the datasets were divided into two to be used in training and testing stages. With the help of the model, PM10 predictions were made between 2004 and 2005.

Besides the measurement, transportation and estimation considerations of PM10 concentrations, the health effects of PM10 are also of considerable importance. Hapçıoğlu et al. (2006) examined the monthly averages of outdoor air quality data and meteorological data measured between 1997-2001 and the applications made to the emergency department due to Chronic Obstructive Pulmonary Disease (COPD) in Istanbul University Hospital in the same period. A total of 1,586 patient records were used. A positive correlation was found between the number of admissions due to COPD and PM10.

In the study conducted by Buldur and Sarı (2018), it was stated that air pollution in Isparta is above national standards from time to time between November and the end of March. They revealed that there is a higher level of air pollution in Isparta, especially in the winter season, as in many cities in Turkiye, and that topographic and climatic factors, which are not the source of pollution but acted as a conduit for air pollution, have significant effects on the pollution in the city.

The national air pollution report of 2017 stated that, Manisa was at the top of the list of provinces with the highest levels of air pollution, although efforts to improve air quality continued. In the years between 2009-2017, PM10 changes in Manisa for the months of December and January were evaluated in consideration with the EU limit values and the annual limit values determined by national regulation. It was concluded that the annual PM10 pollution in Manisa's air quality was about two times higher than the EU limit values, and that air pollution in the city decreased completely under the influence of meteorological parameters, especially wind speed (Yılmaz, 2018).

Giri et al. (2008) conducted a study on the effects of meteorological conditions such as temperature, precipitation, humidity, atmospheric pressure, and the direction and speed of wind on PM10 concentration between March 2003 and December 2005 in Nepal's Kathmandu Valley. This study showed that PM10 concentration had a negative relationship with precipitation and humidity, and a positive relationship with wind speed and atmospheric pressure.

Another study by Huebnerova et al. (2014) estimated daily PM10 concentrations in Brno, Czech Republic. With the help of available meteorological data, including temperature, wind speed and direction, and amount of cloud cover, PM10 concentration estimation was made using a linear model. The PM10 concentration was also tried to be estimated with the predicted meteorological parameters, but no successful results could be obtained. Therefore, the study was carried out with the meteorological data measured at the station.

İbrahimova (2013) developed correlations between the air pollution (SO_2) data measured from July 2012 to March 2013 in the Baku city center and the meteorological data collected in the same time period by using statistical methods. As a result, it was found out that there was a relationship between the concentration of SO_2 pollutants and temperature, humidity, pressure, precipitation, and wind.

Asrarı et al. (2006) conducted an air quality analysis with SO_2 measurements of the period between 1995 and 2002 in Tehran-Iran. The main purpose of this study was to show the effects of meteorological factors on pollutant concentration. The relationship between meteorological parameters and pollutant concentration was expressed with a linear regression equation. This equation shows that wind speed, daily temperature, and humidity have inverse effects on SO_2 concentration.

In the study conducted by Çıldır and Mutlu (2021), temporal and spatial analysis of PM10 and SO_2 concentrations were performed in the city center of Balıkesir under the influence of meteorological factors. The levels of meteorological parameters (temperature, wind speed, humidity, pressure) and air pollutants were examined statistically. The results indicated that PM10 concentrations were at maximum level especially in late autumn and winter months. The meteorological parameters with the highest correlation coefficient regarding the changes in PM10 and SO_2 levels were determined as wind speed and temperature, respectively.

Serdar et al. (2021) statistically examined the changes in PM10 values measured at three stations (İstasyon Kavşağı, Meteoroloji, Başöğretmen) in the center of Sivas between 2016 and 2020. The average values of the measurements were compared according to the years and stations and with the limit values given in the Air Quality Assessment and Management Regulation (RAQAM). Variance analyses were conducted to determine whether there was a difference between the levels and 24-hour limit values of PM10 stated in the regulation compared to PM10 values obtained from the stations throughout the relevant time period. There was no significant correlation between PM10 values measured in 2017 and 2018 at the İstasyon Kavşağı AQMS, nor between PM10 comparisons from Meteoroloji AQMS and Başöğretmen AQMS in 2019 and 2020.

No study was found in the literature that examined the relationship of PM10 with meteorological parameters for the northern region of İzmir. Therefore, with this thesis, it is aimed to contribute to the literature by examining the relationship of PM10 pollutant, which is formed as a result of fuel combustion and industrial activities, with meteorological factors in the northern İzmir.

CHAPTER 4

STUDY AREA-İZMİR PROVINCE

İzmir is a typical example of the Aegean coastal region. Surrounded by the Madra Mountains in the north, Kuşadası Bay in the south, the Tekne Burnu of the Çeşme Peninsula in the west, and Aydın and Manisa provinces in the east, İzmir embraces the bay named after it in the west. Location map of İzmir is given in Figure 4.1. The territory of the province lies between 37° 45' and 39° 15' north latitudes and 26° 15' and 28° 20' east longitudes. The length of the province in the north-south direction is approximately 200 km, and its width in the east-west direction is 180 km. It has a surface area of 12,012 km^2.

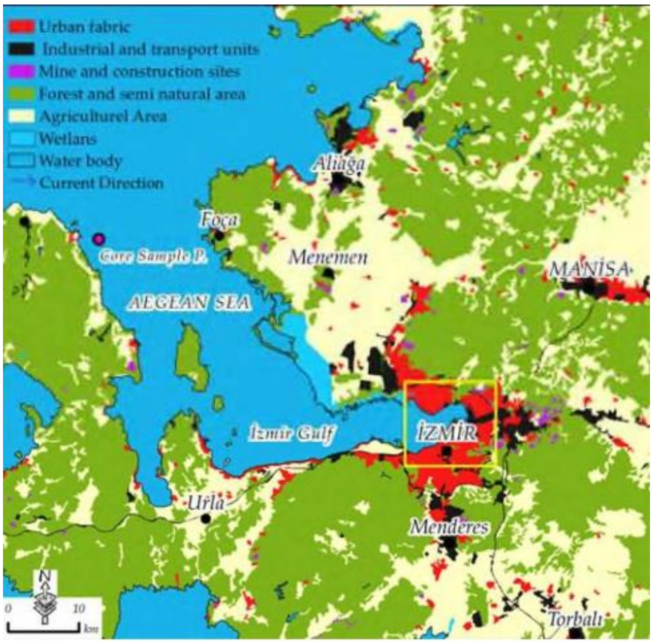

Figure 4.1. Location map of İzmir Inner Gulf.
(Source: Ozkan, 2021)

4.1. Population

İzmir is the third largest city of Turkiye and has has 30 districts: Aliağa, Balçova, Bayındır, Bayraklı, Bergama, Beydağ, Bornova, Buca, Çeşme, Çiğli, Dikili, Foça, Gaziemir, Güzelbahçe, Karabağlar, Karaburun, Karşıyaka, Kemalpaşa, Kınık, Kiraz, Konak, Menderes, Menemen, Narlıdere, Ödemiş, Seferihisar, Selçuk, Tire, Torbalı and Urla. According to the results of the 2021 census, the total population is 4,425,789.

4.2. Climate Conditions

İzmir has a hot Mediterranean/dry-summer subtropical climate which corresponds to Csa in Köppen-Geiger classification (Figure 3.2) (http://koeppen-geiger.vu-wien.ac.at/present.htm).

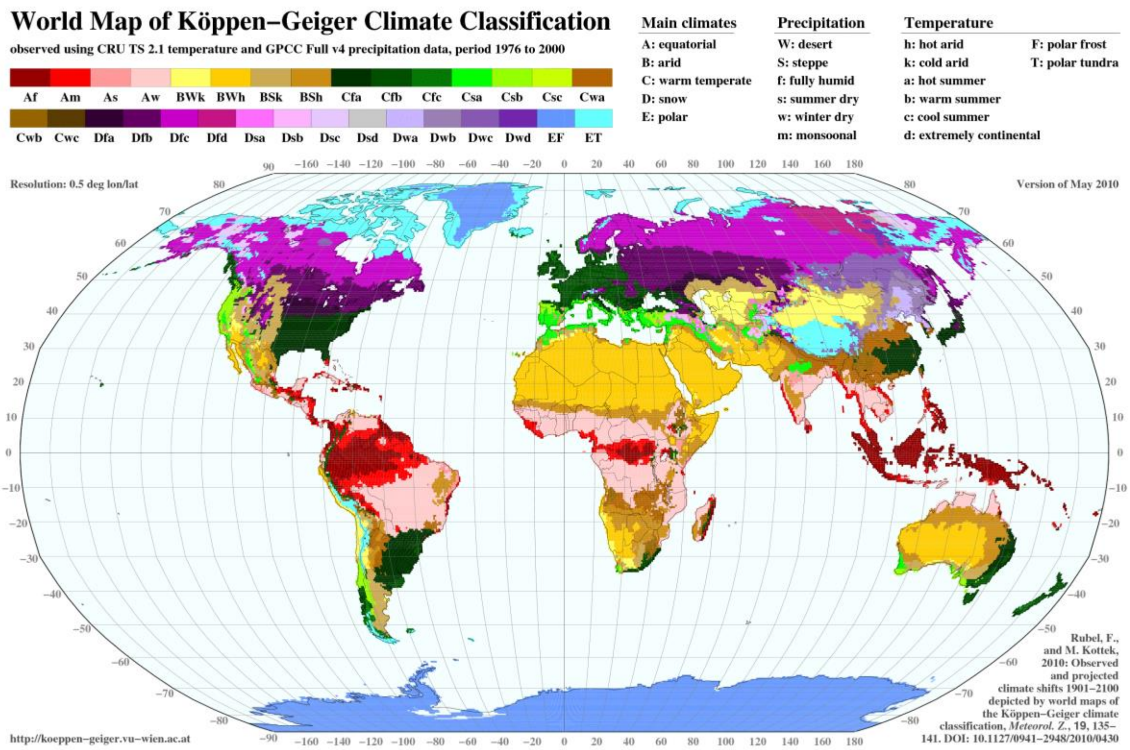

Figure 4.2. World Map of Köppen-Geiger climate classification calculated from observed temperature and precipitation data for the period 1976-2000 on a regular 0.5 degree latitude/longitude grid .
(Source: http://koeppen-geiger.vu-wien.ac.at/present.htm)

Summers are dry and hot due to the domination of subtropical high-pressure systems while winters experience moderate temperatures and changeable, rainy weather due to the polar front. These climates usually occur on the western sides of continents between the latitudes of 30° and 45°. Vegetation is adapted to the dry summers and is fragrant and oily making it susceptible to fire. The typical Mediterranean climate average monthly temperatures in excess of 22°C in its warmest month and an average in the coldest month between 18 to -3°C with at least four months above 10°C.

Based on 83 years' worth of data collected between 1938 and 2021 by the Turkish State Meteorological Service, the annual average temperature of İzmir is 17.9°C. According to this measuring period, the highest average temperature is 22.7°C and the lowest average temperature is 13.6°C.

Yildiz et al. (2014) investigated annual cooling energy loads for 2012, 2020, 2050 and 2080 using the UK Handley Center's third generation coupled atmosphere-ocean global climate model (HadCM3) in low-rise apartment buildings in İzmir. Simulation results for the 2020s, 2050s, and 2080s indicate an increasing trend in annual cooling energy loads and a reduction in heating requirements. The annual cooling energy loads are more than 2.5 times the annual heating loads in the 2020s, 4.5 times in the 2050s, and 7 times in the 2080s. The high differences between annual heating and cooling energy loads may be due to the future global warming. Based on the study, the annual mean temperature will increase approximately 4°C and the solar radiation will increase 5% but the relative humidity will decrease 10% by the 2080s in İzmir.

4.3. Economic Structure

İzmir's economy stands out with its multi-sectoral structure and exporter character. In the light of the latest published data, it is seen that 57% of the added value produced in İzmir's economy comes from the service sector, with 38% from the industrial and 5% from the agriculture sectors. Aliağa, Bornova, Çiğli, Gaziemir, Kemalpaşa, Menderes, Menemen, and Torbalı districts are the districts where industrial investments are concentrated. The Aegean Free Zone (ESBAŞ) in Gaziemir and the İzmir Free Zone (İZBAŞ) in Menemen are the two important trade zones of the city. The share of the industrial sector is above the country average and covers approximately

7% of the country's exports. In the last three years, the foreign trade balance has resulted in a surplus in favor of exports. Although its share of the agricultural sector is below the country average, the fact that it ranks first in many product groups at the country scale indicates the productivity level that İzmir has reached in this sector.

According to the "İzmir Regional Input-Output Analysis" conducted by the İzmir Development Agency and published in June 2021, the biggest contribution of İzmir (in terms of added value) to the country's economy is procured by the "water transportation", "refined petroleum products" and "paper and paper products manufacturing” sectors respectively.

İzmir is under intense environmental pressure due to heavy industrial facilities on the northern axis, intensive agricultural production in the Küçük Menderes Basin and Bakırçay Basin, as well as the dense urban population and tourism activity extending to the city center and the peninsula region. İzmir alone produces one fourth of the hazardous wastes in the country and has the potential to be water poor due to the presence of sectors that use water intensively in both industry and agriculture. Studies indicate the danger of drought for the Küçük Menderes Basin in the next 10 years (https://kalkinmaguncesi.izka.org.tr/).

4.4. İzmir Province Meteorological Condition and Air Quality

Temperature, sunshine duration and precipitation values of İzmir province between 1938-2021 are shown in Table 4.1 (https://mgm.gov.tr).

In wintertime, poor meteorological conditions, especially inversion, are serious issues in İzmir. Air pollution due to inversion (temperature reversal) is affected by industrial pollution and low-quality fossil fuels. As a result, both air temperature and air pollution increase. Additionally, northerly winds blowing through the Bornova lowland bring additional air pollution to the city from the industrial facilities located both in Bornova and the Kemalpaşa lowlands.

Table 4.1. Temperature and precipitation values of İzmir province between 1938-2021. (Source: https://mgm.gov.tr)

İZMİR PROVINCE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Average temperature (°C)	8.8	9.6	11.7	15.8	20.8	25.4	27.9	27.7	23.7	18.9	14.3	10.5
Highest average temperature	12.4	13.6	16.3	20.9	26.1	30.7	33.2	33	29.2	24	18.6	14.1
Lowest average temperature (°C)	5.8	6.2	7.7	11.1	15.5	19.8	22.5	22.4	18.7	14.6	10.8	7.6
Average sunshine duration (hours)	4.3	5.2	6.4	7.9	9.8	11.6	12.3	11.9	10.1	7.6	5.6	4.2
Average number of days with precipitation	12.82	11.47	10.47	7.47	6.82	4.06	0.29	0.71	2.76	5.59	8.82	12.88
Monthly average of total precipitation amount (mm)	136.9	102.9	75.8	46	31.5	12.3	4.1	5.6	15.3	44.6	92	146.8
Highest temperature (°C)	22.5	27	30.5	32.5	37.6	41.3	42.6	43	40.1	36	30.3	25.2
Lowest temperature (°C)	-8.2	-5.2	-3.8	0.6	4.3	9.5	15.4	11.5	10	3.6	-2.9	-4.7

Figure 4.3 shows the sectoral greenhouse gas emissions of İzmir. The total greenhouse gas (CO_2 + CH_4 + NO_2) emissions from industry account for 31.4% while buildings are responsible for 15%. Green urban areas contribute to climate change mitigation by directly removing greenhouse gasses from the atmosphere via photosynthetic uptake. Therefore, these values can be decreased by increasing green urban areas (İzmir Metropolitan Municipality, 2020).

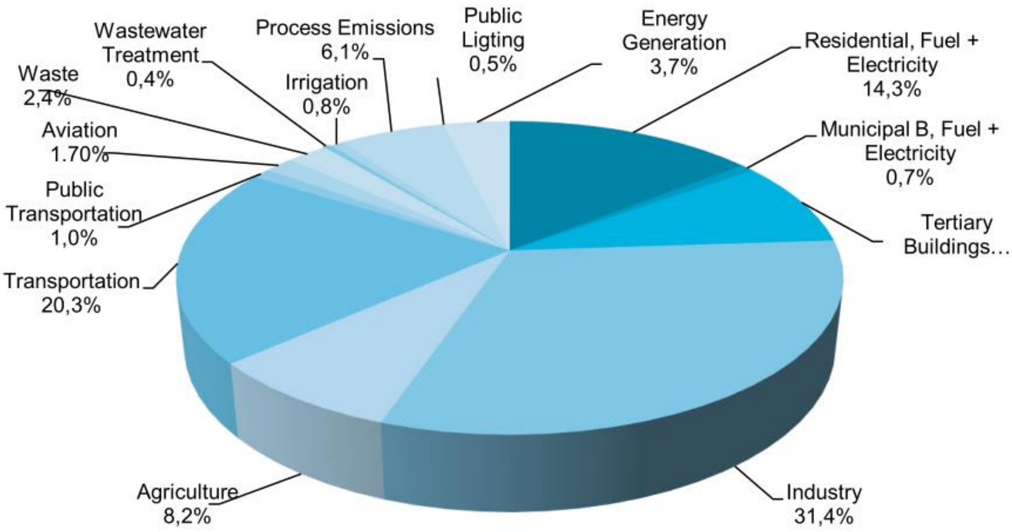

Figure 4.3. İzmir Baseline Emissions Inventory.
(Source: İzmir Metropolitan Municipality, 2020)

Quality of air in İzmir changes according to season and location in the city. It has been observed that traffic and weather conditions are two important parameters. Dumanoglu and Bayram (2013) were collected air quality data (O_3 and CO_2 concentrations) in; inner city and rural hinterland of İzmir. The authors were determined ambient air O_3 and NO_2 concentrations by passive samplers located at urban, sub-urban, rural, and industrial sites. The highest NO_2 concentrations were measured at urban sites with heavy traffic. However, the highest O_3 concentrations were measured at rural sites. While the highest O_3 concentrations were measured in summer, concentrations were also relatively high in winter. The authors were examined correlations between O_3 levels and several meteorological parameters such as solar radiation, temperature and relative humidity were examined. Results indicated that both solar radiation and temperature had significant correlation with O_3 concentrations while humidity had a very low correlation.

Other sources of air pollution in İzmir are industrial facilities and combustion systems used for heating in winter months. The share of these sources in the pollution within the borders of İzmir province varies according to the pollutants; industrial facilities become more important sources of SO_2, while particulate matter is sourced mostly by domestic heating. In NO_x, VOC and CO, traffic becomes a more important source. Cement factories, quarries and gravel plants, asphalt plants, and iron and steel factories in the immediate vicinity of the city are facilities which adversely affect the urban air quality.

Industrial facilities in the Aliağa region pose a serious threat from air pollutants in İzmir. Types of emissions from facilities such as refineries, petrochemicals and iron and steel plants vary by sector. While combustion-related pollutants and organic pollutants are the major emissions from the refinery and Petkim, dust emissions are more significant from iron and steel plants. Dust emissions originating from materials (scrap, slag and flue dust kept in filters) coming out of the chimneys of iron and steel plants include different elements and dangerous organic pollutants. The location of İzmir Atatürk Organized Industrial Zone (IAOIZ) is shown on the map in Figure 4.4 (https://www.google.com/maps). Since the prevailing wind direction in İzmir are from the north, the pollutants formed in the Aliağa region are transported to İzmir. Due to the fact that the industrial facilities in the region are energy-intensive facilities, the port and other advantages, Aliağa is also an attractive region for energy producers, and there are attempts to establish new thermal power generation plants here.

Figure 4.4. Locations of the industrial plants in IAOIZ on the map (https://www.google.com/maps)

CHAPTER 5

METHODOLOGY

In this study, the effects of meteorological parameters on the PM10 pollutant were investigated. The study was carried out in two locations: Vilayetler Evi Hotel and Sasalı Natural Life Park. In these locations, the relevant data was collected from meteorological stations which were installed within the scope of the European Union's Horizon 2020 project. PM10 data was obtained from the Çiğli, Karşıyaka, Bayraklı air quality monitoring stations of the Ministry of Environment and Urbanization. These stations were selected according to urban-nature continuum principles. Each station area corresponds to a different environmental problem. Karşıyaka and Bayraklı stations are located in densely urbanized areas with high population and traffic. The high number of vehicles and high rise buildings surrounding them are the biggest factors causing air pollution for these regions. In the region where Çiğli station is located, air pollution is experienced especially in winter months due to the use of fossil fuels. Although natural gas is commonly used for heating unfortunately, low-income neighborhoods in Çiğli district still use fossil fuels. Additionally, Çiğli station is also affected by the IAOIZ located nearby. The data used in this study were examined in two groups: compiling of PM10 and meteorological parameters of the study area, and statistical analysis.

5.1. Data Collection

The PM10 data are measured and stored at www.havaizleme.gov.tr website where air quality measurement data can be viewed online and historical data can be accessed.

Table 5.1 shows the measured parameters, coordinates and installation dates of the stations. Additionally, the locations of the three air quality monitoring stations selected for the study are shown on the map in Figure 5.1 (http://sim.csb.gov.tr).

Table 5.1. Air quality monitoring station information (Source:http://sim.csb.gov.tr).

Station Name	Parameters Measured	Parameters Measured - Coordinates		Launch Date
		Latitude	Longitude	
Çiğli	PM10-PM2.5-SO_2	38.494026	27.062764	2009
Bayraklı	PM10-SO_2	38.466569	27.179521	2009
Karşıyaka	PM10-SO_2	38.453673	27.112168	2002

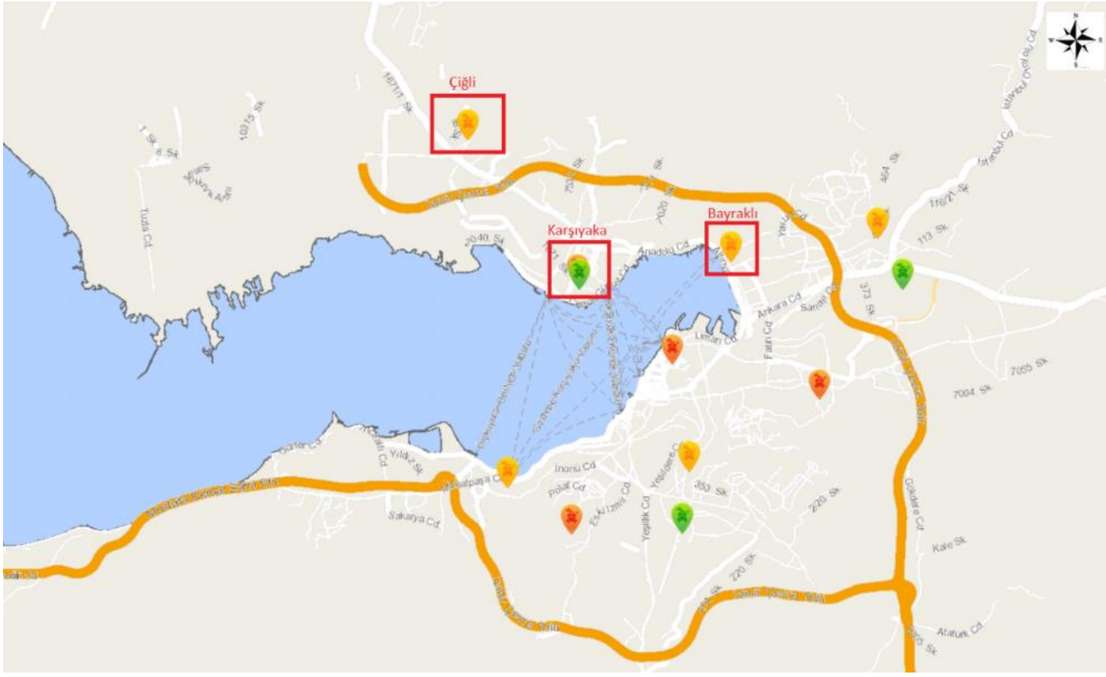

Figure 5.1. Locations of İzmir province air quality stations on the map.
(Source: http://sim.csb.gov.tr)

Çiğli Air Quality Monitoring Station, located on the Çiğli Public Education Center Campus, is placed at the border of a 6,150 m^2 green area. The İzmir Ring Road passes 2 km south of it. It is partially surrounded by the IAOIZ from north to south, approximately 3 km west of it. It can be considered as being located in an area where air pollution is intense.

Figure 5.2. Picture of Çiğli air quality monitoring station.
(Source: taken by the author)

Bayraklı Air Quality Measuring Station is located in a 10,000 m^2 park. The area where the station is situated on the border of a playground. It is 18 km away from IAOIZ to the north. Bayraklı costline is located 2 km west of it, and a busy highway runs along its coastline. It can be said that the park, which has (3-4)-storey apartments in its immediate surroundings.

Figure 5.3. Picture of Bayraklı air quality monitoring station.
(Source: taken by the author)

Karşıyaka Air Quality Measuring Station, located on the campus of the Karşıyaka Regional Directorate of Forestry, is surrounded by low-rise buildings. Its distance to the Aegean Sea from the east, west and south is 1 km on average. It is 9 km away from the IAOIZ, located in the northwest.

Figure 5.4. Picture of Karşıyaka air quality monitoring station.
(Source: taken by the author)

Figure 5.5 shows the locations of the air quality monitoring stations and the overall built environment around the stations. It is seen that there is no building density around Çiğli station. In contrast, Karşıyaka and Bayraklı stations are close to the highway on the coastline. Therefore, it is possible for the air pollution values to be high due to traffic.

To evaluate the effect of meteorological parameters on PM10, both meteorological parameter and PM10 data were collected. The hourly PM10 concentration values recorded by Karşıyaka, Çiğli and Bayraklı air quality monitoring stations in 2017-2021, were collected from http://sim.csb.gov.tr. The data were converted to monthly averages.

(a)

(b)

Figure 5.5. Aeiral views showing the surrounding areas of each stations
(a) Karşıyaka, (b) Bayraklı, (c) Çiğli.
(Source: http://sim.csb.gov.tr)

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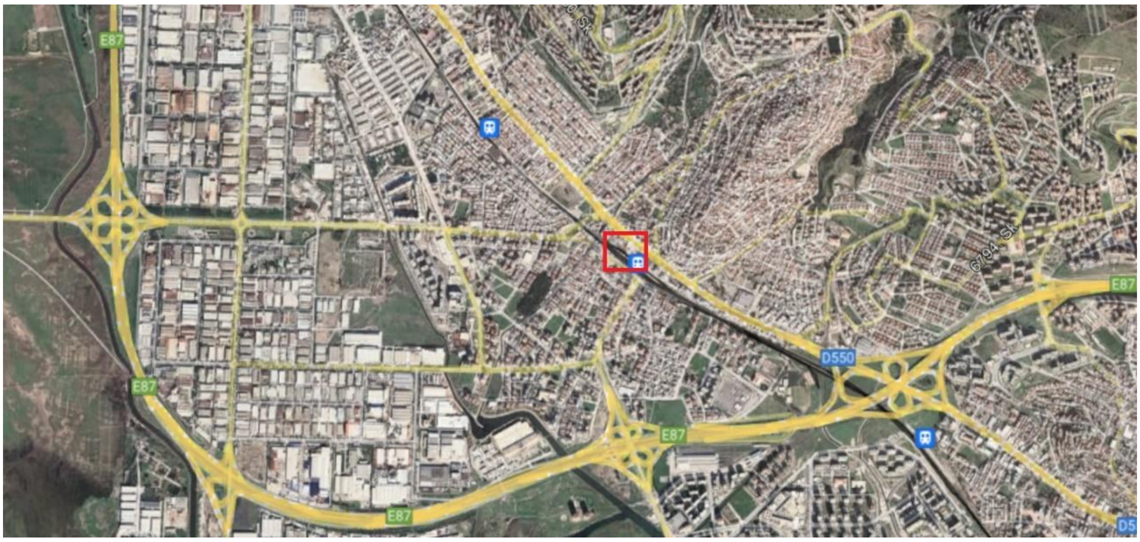


(c)

Figure 5.5 (cont.)

The meteorological parameters used in the study are wind speed (WS), wind direction (WD), temperature (T) and relative humidity (RH). Two HOBO RX3000 meteorological stations were installed to two case study areas, Vilayetler Evi Hotel and Sasalı Natural Life Park (Figure 5.6). The sensor specifications of the meteorological stations are given in Table 5.2 (https://www.hobodataloggers.com.au/rx3000). Installation of the meteorological stations were planned in 2020 but it was postponed to 2021 because of the frequent pandemic-related curfews. Therefore, meteorological data was collected between February 2021 and January 2022, although a 5-year data of the PM10 concentration exist.

Meteorological stations collect data at 10-minute intervals. Since the PM10 data recorded hourly at the Air Quality Monitoring Stations, meteorological data were also converted to hourly averages.

Table 5.2. Sensor specifications of HOBO RX3000 meteorological station.
(Source: https://www.hobodataloggers.com.au/rx3000)

Specifications	Wind speed	Wind direciton
Measurement range	0 to 76 m/s (0 to 170 mph)	0 to 355 degrees, 5-degree dead band

(cont. on next page)

Table 5.2 (cont.)

Maximum wind speed survival	76 m/sec (170 mph)	67 m/sec (150 mph)
Accuracy	± 1.1 m/s (2.4 mph) or ± 4% of reading whichever is greater	± 5 degrees
Resolution	0.5 m/s (1.1 mph)	1.4 degrees
Operating temperature range	-40°C to +75°C	-40°C to +70°C
Specifications	**Temperature**	**RH**
Measurement range	-40 to 70°C	0 to 100% RH, -40° to 70°C
Accuracy	±0.25°C from -40 to 0°C	±2.5% from 10% to 90% (typical) to a maximum of ±3.5% including hysteresis at 25°C; below 10% RH and above 90% RH ±5% typical
Resolution	0.02°C	0.01%
Response time	17 minutes in air moving 1 m/sec	30 seconds in air moving 1 m/sec

(a) (b)

Figure 5.6. HOBO RX3000 meteorological station installations.

(a) Vilayetler Evi Hotel, (b) Sasalı Natural Life Park

5.2. Data Analysis

The regression model is a technique used for predicting the relationship between dependent and independent variables, analyzing and modeling the data used to predict the normal relationship between variables. Regression techniques are applied to the processed datasets to achieve accuracy. Prediction using regression models can be performed by several methods, such as support vector regression (SVR) (Liu et al., 2019), linear regression (LR), decision tree regression (DTR) (Shih et al., 2019), and Lasso regression (LR) (Pandya et al., 2020). In this thesis, using PM10 as the dependent variable, linear regression was applied for each independent variable.

5.2.1. Statistical Analysis

In this section, the statistical significance and practical significance of the data were examined. The significance between meteorological parameters and PM10 was examined with t-test method. Firstly, a null hypothesis (H_0) was made to examine this correlation for each parameter:

-There is no positive and significant relationship between PM10 and WS.

-There is no positive and significant relationship between PM10 and WD.

-There is no positive and significant relationship between PM10 and T.

-There is no positive and significant relationship between PM10 and RH.

All hypothesis tests were checked with one-tailed t-test. The number of tails depends on whether the mean or the ratio of a group in the hypothesis test is greater or less than the other group, whether it is in one direction or not, or whether it is equal. In this study, a one-tailed t-test was used because negativity and positivity were important when examining the differences between variables. To test the statistical significance, the p-value was calculated after the t-value.

The hypothesis was analyzed for variables at a 5% significance level (α=0.05). Alpha (α) (significance level) is the threshold value that meets the p values. The null hypothesis was rejected if p-value is found to be lower than 0.05. Statistical significance (p-value) is the probability that the observed difference between the two groups is due to chance. However, the p-value alone does not provide enough information about how much error the H_0 hypothesis contains. As a further study, a detailed strength level for the linear model between two variables is conducted with Coefficient of Determination (R^2) analysis.

5.2.2. Effect Size Control

After statistical significance is found practical significance is applied with effect size. It is important to consider practical significance, which shows that the effect is large enough to be meaningful in the real world because statistical significance alone can be misleading for large data sets. Practical significance is represented by the effect sizes. “Effect Size (ES)” is an easy way to measure the effectiveness of a particular intervention. It is simple to calculate, understand, and apply to any measured result in many areas (Serdar et al., 2021).

Effect size provides a more scientific approach to the size of an intervention or its effectiveness, rather than statistical significance. Therefore, it is an important tool for reporting and interpreting the event. The effect size statistics used to compare the means of two continuous variables are obtained by dividing the difference of the group means by the standard deviation (Turhan and Özbey, 2021).

The Pearson Correlation Coefficient (r-value) was used for the examination of the effect size. However, since there were no two different experimental groups in this study, r-value was taken into consideration instead of Cohen’s d.

This coefficient defined by Karl Pearson as given in Equation 1.

$$\rho_{X,Y} = \frac{Cov(X,Y)}{\sigma_x \sigma_Y} = \frac{E\big((X - E(X))(Y - E(Y))\big)}{\sigma_x \sigma_Y} \tag{1}$$

X and Y are $E(X)=\mu_X$, $E(Y)=\mu_Y$ and their finite variances are $\sigma_X^2 = Var(X)$, $\sigma_Y^2 = Var(Y)$.

The “Product-Moment” notion in the correlation coefficient comes from the equation $= \mu_{11}/\sqrt{\mu_{20}\mu_{02}}$, where $\mu_{ij} = E\left[(X-\mu_X)^i (Y-\mu_Y)^j\right]$, *(i,j)* is the moment product. “Pearson Product-Moment Correlation Coefficient” will be referred to as “Pearson Correlation Coefficient” in this study. The following properties can be written for the Pearson Correlation Coefficient:

i. $|\rho| \leq 1$ inequality is a result of Cauchy-Schwarz inequality. Correlation coefficient cannot exceed the limits of ± 1.

ii. If Y is increasing while X is increasing (or if X is increasing while Y is increasing) correlation coefficient becomes positive, if Y is decreasing while X is increasing (or if X is decreasing while Y is increasing) correlation coefficient becomes negative.

iii. If there is no correlation between X and Y random variables, then $\rho = 0$, but the reverse may not be true. When the correlation coefficient is 0, it can be said that there is no linear correlation between the two variables (Cohen et al., 2006).

5.2.3. Coefficient of Determination (R^2-value)

The R^2 value shows the strength of the relationship between the two variables in the linear model (Antognetti et al., 1991). R^2-value is calculated according to Equation 2.

$$R^2 = 1 - \frac{\Sigma_j \left| t_j - o_j \right|^2}{\Sigma_j \left(o_j \right)^2} \quad (2)$$

Here, t is the target value, o is the output pairs.

CHAPTER 6

RESULTS AND DISCUSSION

All collected data and statistical analysis results are presented in this section. Firstly, PM10 data obtained from the website of the Ministry of Environment and Urbanization, then meteorological data collected from the meteorological stations located in study areas (Vilayetler Evi and Sasalı Natural Life Park).

Table 6.1 shows monthly averages of PM10 data of Karşıyaka, Çiğli ve Bayraklı air quality monitoring stations between 2017-2021. It can be seen from the Table that the highest PM10 values are measured at Bayraklı air quality monitoring station. The average value of January, February and December 2017 are encountered as 63.6 $\mu g/m^3$ in Bayraklı. This value increases to 76.1 $\mu g/m^3$ on January and December 2018. Likewise, a decrease is observed for the 2020 and 2021 periods in Bayraklı. The comparison of the temporal evolution of PM10 concentration in the period from 2017 through 2021 over the first six-month period shows a steady decrease of PM10 concentrations. When the annual PM10 averages are examined, there is an 24% decrease in 2019 compared to the previous year. In 2020, an increase of 2% is observed.

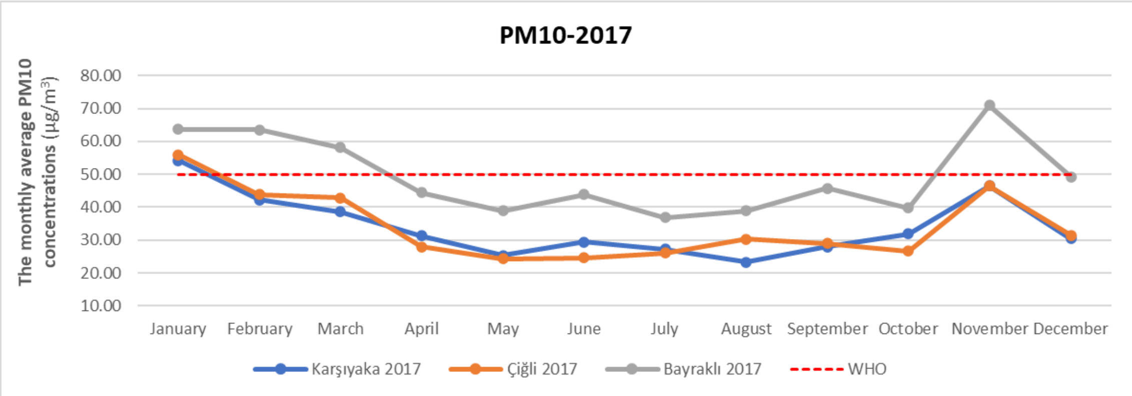
Also, at Çiğli station, the highest PM10 value measured was 57 $\mu g/m^3$ in November 2020. In the first three months (December 2020, January 2021 and February 2021), the monthly average decreased to 43 $\mu g/m^3$, 38.5 $\mu g/m^3$ and 39.8 $\mu g/m^3$, respectively. For the annual PM10 averages, the highest PM10 average belongs to 2017 with 35.8 μ/m^3. The largest decrease in PM10 average was observed between 2020 and 2021 at 20%. The greatest increase in annual PM10 value was observed between 2019 and 2020 at 13%.

At Karşıyaka station, the highest PM10 value measured was 54.1 $\mu g/m^3$ in January 2017. While a 16.4% decrease is observed in the annual average PM10 value between 2017 and 2018, an increase of 18.90% is observed between 2019 and 2020.

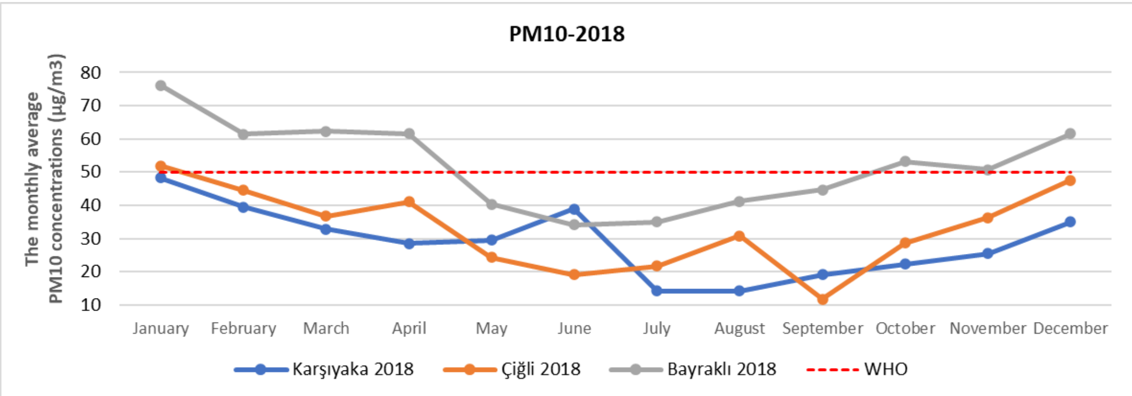
Table 6.1. Monthly average PM10 values for three stations by years.

Years	Stations	January (µg/m3)	February (µg/m3)	March (µg/m3)	April (µg/m3)	May (µg/m3)	June (µg/m3)	July (µg/m3)	August (µg/m3)	September (µg/m3	October (µg/m3	November (µg/m3	December (µg/m3	Average (µg/m^3)
2017	Karşıyaka	54.1	42.2	38.6	31.2	25.3	29.3	27.2	27.9	31.8	46.4	30.5	54.1	35.5
	Çiğli	55.9	43.9	42.8	27.9	24.4	24.7	26.1	29.1	26.6	46.5	31.5	55.9	35.8
	Bayraklı	63.6	63.6	58.1	44.5	39.0	43.9	36.8	45.7	39.7	70.9	49.2	63.6	50.5
2018	Karşıyaka	48.3	39.5	32.9	28.6	29.5	38.9	14.2	19.2	22.4	25.5	35.0	48.3	30.5
	Çiğli	51.9	44.5	36.7	41.1	24.4	19.1	21.8	11.8	28.6	36.3	47.6	51.9	34.3
	Bayraklı	76.1	61.5	62.3	61.6	40.4	34.2	35.0	44.8	53.2	50.8	61.5	76.1	53.7
2019	Karşıyaka	21.3	29.9	18.9	16.1	19.6	21.6	21.6	21.9	32.3	48.5	45.1	21.3	26.6
	Çiğli	44.9	40.6	26.2	19.0	20.9	26.0	26.1	28.0	35.9	36.3	42.1	44.9	31.8
	Bayraklı	53.5	53.7	41.8	32.4	35.7	40.8	36.8	38.7	56.4	56.8	49.6	53.5	45.0
2020	Karşıyaka	42.0	34.5	29.8	17.2	12.5	23.4	30.6	34.9	39.6	45.3	46.7	42.0	32.8
	Çiğli	43.0	30.7	30.2	24.1	22.6	17.8	26.7	30.3	49.3	44.1	57.0	43.0	34.1
	Bayraklı	48.9	36.8	37.9	27.5	27.5	24.7	32.0	37.8	41.5	43.4	55.0	48.9	38.2
2021	Karşıyaka	36.9	38.6	31.1	30.6	31.0	28.4	29.6	30.7	29.3	29.9	20.3	36.9	31.3
	Çiğli	38.5	39.8	27.7	23.7	23.3	23.6	25.1	24.0	23.6	39.3	30.3	38.5	29.7
	Bayraklı	46.7	49.2	34.8	30.6	34.0	35.6	40.2	32.1	31.8	58.1	24.8	46.7	38.2

When PM10 concentrations are evaluated seasonally, they appear to be at low levels in the summer months, while they are higher in the winter and spring months; however, no significant episodic period has been observed. Heating season in İzmir starts in October and ends in April. March are Emission of combustion gases from heating systems are the source of air pollution in this season. Along with the increase in fossil fuel use, the traffic is more intense in the winter months causing higher PM10 concentrations. In the summer months, concentrations were lower due to the decrease in traffic density with the school holidays and the decrease in PM10 concentrations originating from combustion. These changes in summer and winter months for all three stations can be seen in Figure 6.1.



(a)



(b)

Figure 6.1. Monthly average PM10 values for 2017-2021. (a) 2017, (b) 2018, (c) 2019, (d) 2020, (e) 2021.

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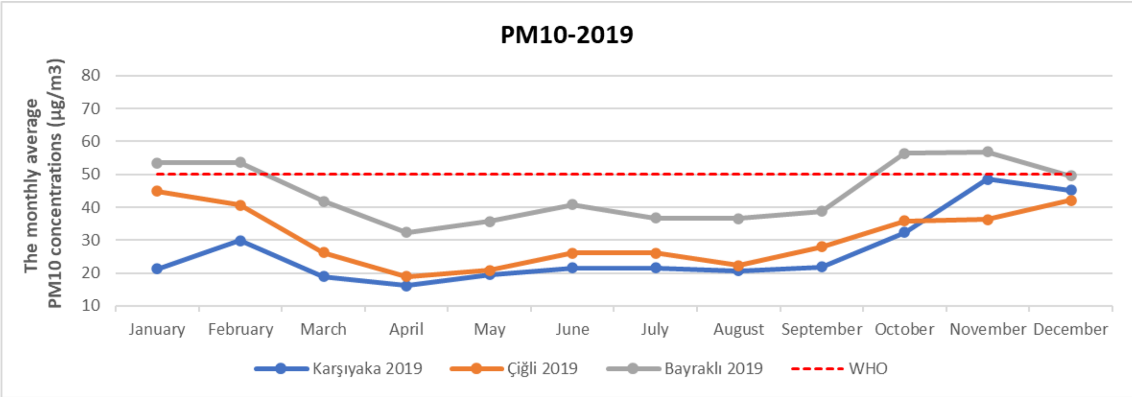

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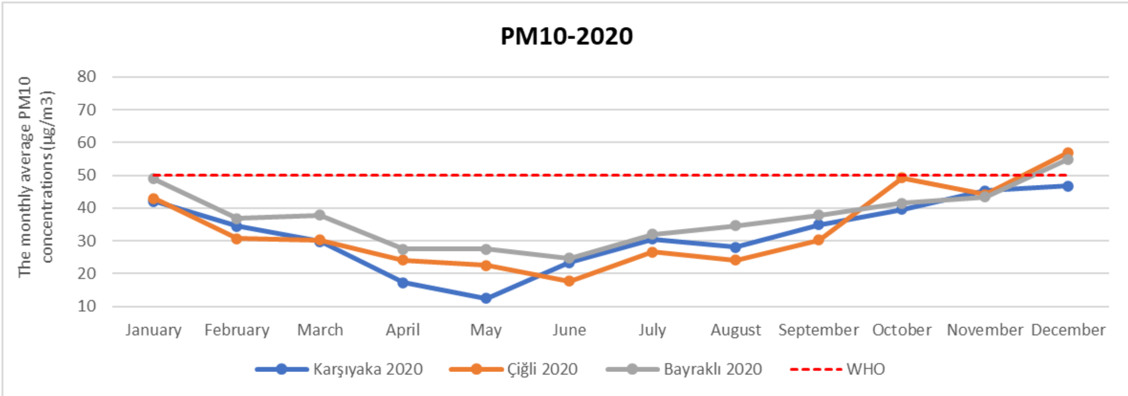
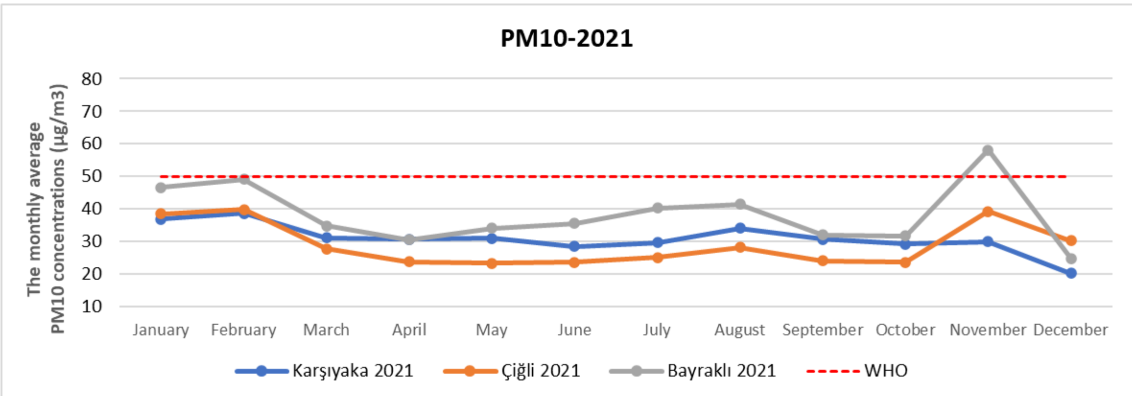


(d)



(e)

Figure 6.1 (cont.)

Figure 6.1 also indicates that the PM10 limit value (50 µg/m^3) set by the EU and WHO is exceeded, especially in Bayraklı station during winter months. The fact that Bayraklı station is close to the coastal highway causes this station to be affected by a heavy traffic. On the other hand, Çiğli station is located in a quiet neighborhood close to the industrial facilities which are the reason for elevated PM10 concentrations.

The PM10 values in 2020 were generally lower than 2018 and 2019 values, within the first six-month period. In addition, the monthly PM10 concentrations show large fluctuations over several consecutive days in 2018 and 2020. For example, it decreased from 80 to 49 $\mu g/m^3$ within the last week of January 2018 (Figure 6.1-b), while the daily PM10 concentration did not change abruptly over several consecutive days during the entire time period examined during 2020. However, there was a sudden increase in the second half of May 2020. The exact reason for this jump is not known but it is considered to be caused by the sudden relaxation of control measures after a lengthy pandemic-related lockdown within the city that resulted in short-lived increased human activity.

If the 2020 pandemic period is evaluated, it can be seen that the PM10 concentrations showed constant decrease. On a yearly basis, the highest decrease occurred in 2018 while 2019 and 2020 values are close to each other and there is no big difference between them. Additionally, PM10 values have decreased in every period and every year compared to the previous year. This result indicates a decrease in PM10 values regardless of COVID-19 measures.

Figure 6.2 and 6.3 show monthly average values of PM10 for winter and summer seasons of 2017-2021 in Karşıyaka, Çiğli, Bayraklı stations. Accordingly, the highest increase of PM10 valuesare observed in summer season for all stations in 2021 with an increase of 30.2% in Karşıyaka, 10% in Çiğli and 27.3% in Bayraklı. The highest increase in PM10 concentrations in winter season is observed at Karşıyaka station with 21% during the transition from 2019 to 2020. PM10 values at Çiğli station is increased 7.8% while a 13.1% decrease is observed at Bayraklı station in the same period. The reason for the increase in PM10 values would be the increase in fuel consumption for heating because of the pandemic lockdown. On the other hand, the decrease in Çiğli station can be explained by the decrease in traffic due to the lockdown.

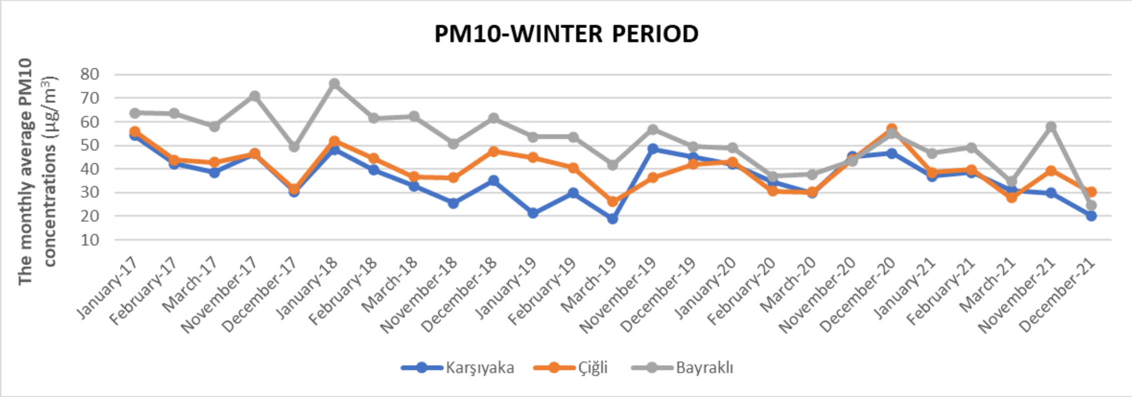


Figure 6.2. Monthly PM10 data for summer period.

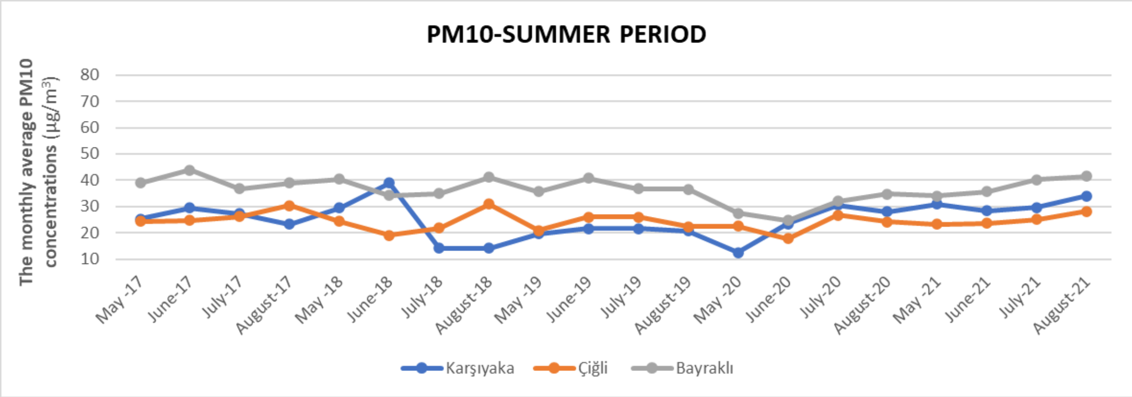


Figure 6.3. Monthly PM10 data for winter period.

The statistical analysis is conducted using the collected PM10 and meteorological data for each study location.

6.1. Vilayetler Evi Hotel

As mentioned in the Methodology Section, one tailed t-test is conducted in the study. Then the p value was calculated according to the related t-value.

To check the practical significance, effect size control is conducted via between PM10 pollutant and meteorological data. PM10 pollution variable was examined as the dependent variable and WS, T, WD and RH as the independent variables.

Based on Table 6.2, the relationship between PM10 and the WS is found significant at level 5% with the p value of 0.022. According to Table 6.3, Pearson r-value is -0.15 showing that there is a significant negative relationship between PM10 and WS with a low effect size. Two variables move in opposite direction, meaning as WS increases, PM10 is expected to decrease and vice versa.

Table 6.2. Evaluation results for Vilatetler Evi.

Input	t-value	p-value
WS (m/s)	1.94	0.022*
T (°C)	0.01	0.985NS
WD (Ø)	2.11	0.001**
RH (%)	2.34	0.001**
*= significant at 1% level, **=significant at 5% level, NS= not significant		

Table 6.3. Analyses of effect size for Vilayetler Evi.

Input	Effect Size (Pearson r-value)
WS (m/s)	-0.15
T(°C)	Null hypothesis was accepted
WD (Ø)	0.4
RH (%)	0.6

The R^2 is used to observe how the variation in PM10 is explained by the dependent variables of WS, T, WD and RH. The effects of all parameters were investigated individually. For this, linear regression was applied separately, with independent variables WS, T, WD, RH and dependent variable PM10. Linear regression results are given in Table 6.4. According to this table, the equation where WS is the independent variable is PM10 = -0.1143WS + 30.1. This equation shows that a 0.1143 unit decrease in WS causes a 1 unit increase in PM10. Figure 6.4 illustrates the change of PM10 with WS.

Table 6.4. Linear regression results for Vilayetler Evi.

PM10 versus parameters	Equation	R^2 value
WS	-0.1143x+30.1	0.27
T	0.0729x+28.51	0.11

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Table 6.4 (cont.)

WD	0.0069x+31.41	0.37
RH	0.0120x+29.33	0.41

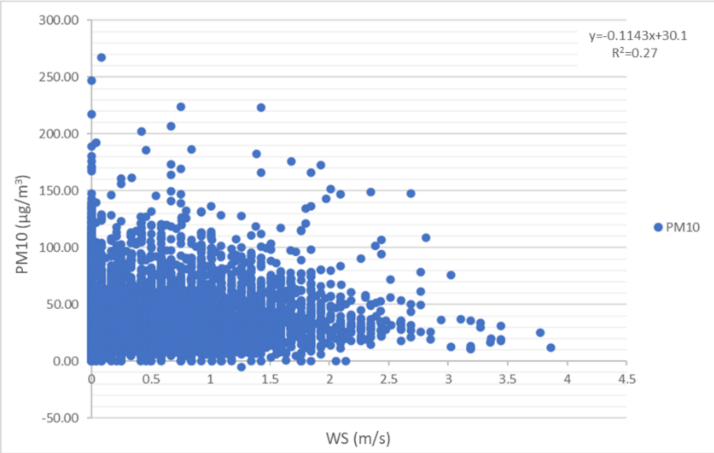

Figure 6.4. Changes in PM10 with WS (Vilayetler Evi).

Figure 6.5 shows the relationship of monthly PM10 averages at each station with WS. The Figure indicates that WS is low in winter months when pollution is most prevalent. This affects air pollution in a negative way. When there is not enough strong wind, polluted air masses cannot be dispersed over the city and negative results may occur. As a result, inversion layers are formed on the city from time to time.

The PM10 levels in Figure 6.5 show that there is a serious decrease in the values in March and April. If we look at the WS for the same months, we see that there is a serious increase in WS. This demonstrates that WS plays a very important role in dispersal of pollution. As seen in the graph, PM10 pollutant concentration decreases significantly as the WS increases.

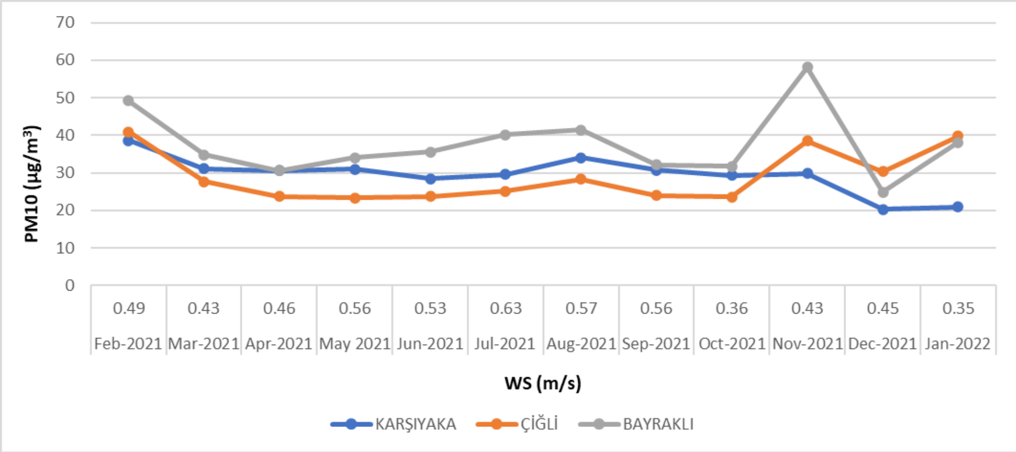

Figure 6.4. Changes in monthly PM10 concentrations and WS for each stations (Vilayetler Evi).

Additionally, no significant correlation was found between T and PM10. In Figure 6.6, it can be seen that during the high-temperature time periods, there are some stretches where the pollution rates increase, as well as periods where they decrease. This situation may be related to the higher pollutant concentrations due to the increase in the number of sources, especially in the winter season compared to the summer season. In other words, it may be related to the decrease in concentrations due to the absence of a heating source in the hot seasons. If this study had been carried out in rural areas of İzmir, positive significant relationships between T and PM10 concentrations could have been determined, because there would be more transport of soil-borne dust into the atmosphere, which causes an increase in coarse particle concentrations. Also, this may be due to the increase in the number of sources, especially in the winter season, and the higher pollutant concentrations compared to the summer season. It shows that other parameters other than T also affect the results.

According to Table 6.4, considering the relationship between T and PM10, an increase of 0.0729 units in T causes an increase of 1 unit in PM10.

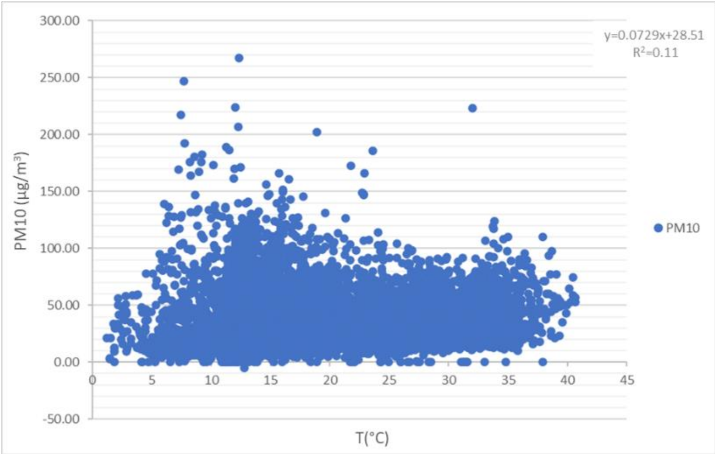

Figure 6.5. Changes in PM10 with T (Vilayetler Evi).

Figure 6.7 shows the relationship between monthly PM10 averages and T. In July, when the highest average T was 30.35°C, the PM10 values at the stations were 34 µg/m^3, 28.2 µg/m^3 and 41.4 µg/m^3 for Karşıyaka, Çiğli and Bayraklı stations, respectively.

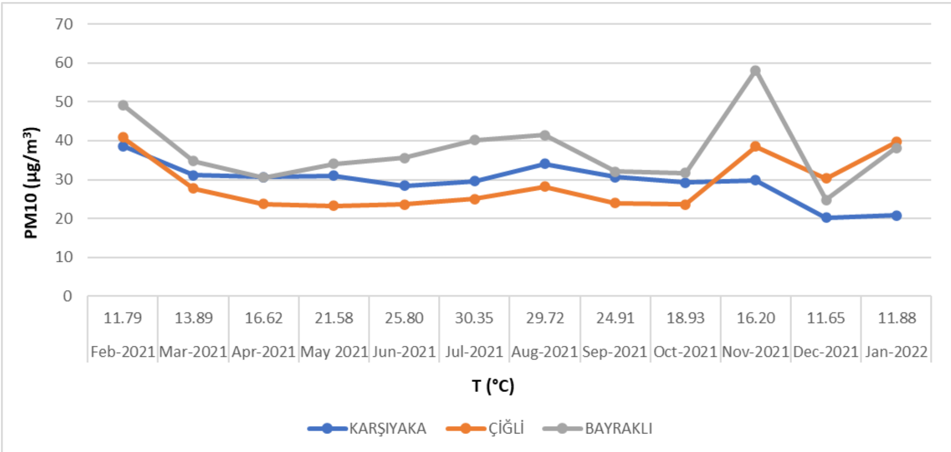

Figure 6.6. Changes in monthly PM10 concentrations with T for each statitons (Vilayetler Evi).

Figure 6.8 shows the variation of PM10 depending on WD. According to Table 6.2, there is a positive significant correlation between WD and PM10 at 5% level with p value of 0.001. The Pearson r-value of this correlation is 0.4, which shows that there is a moderate relationship between the two variables. Based on this result, it can be said that the variables move in the same direction.

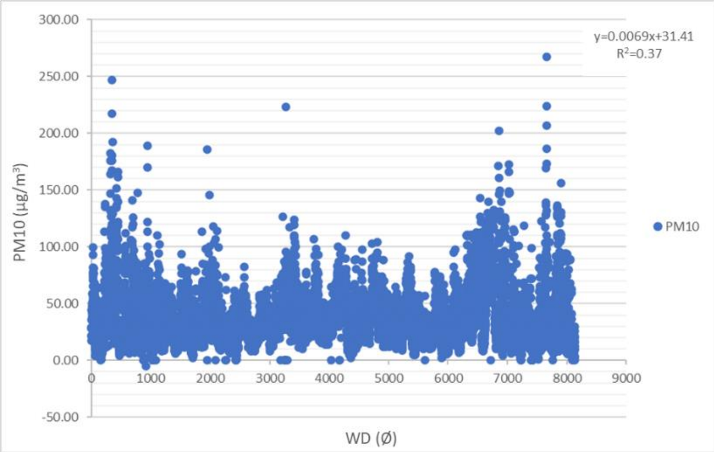

Figure 6.7. Changes in PM10 with WD (Vilayetler Evi).

The prevailing wind direction of İzmir is south-southeast, with the secondary prevailing wind direction being west-northwest, depending on seasonal changes. Therefore, while the wind comes to Karşıyaka from the gulf and residential areas, the wind comes to Çiğli and Bayraklı stations from residential and industrial/commercial areas. Monitoring stations are located in the residential area or at the intersection of the residential area and industrial and commercial units. While Bayraklı Station has mixed land use in its immediate surroundings, Çiğli Station is located in a dense residential area, and the Organized Industrial Zone is located to the southwest. Furthermore, northerly winds blowing through the Bornova lowland bring additional air pollution to study area from the industrial facilities located both in Bornova and the Kemalpaşa lowlands.

According to the measured meteorological data, it has been interpreted that the wind blows mostly from the WSW (West-South-West) direction in both weather stations. In the regression analysis conducted by considering the wind direction, it is observed that the highest PM10 values are measured on the days when the wind is blowing from the WSW (225°-270°) direction.

Figure 6.9 shows the variation of PM10 depending on RH. The relationship between PM10 and RH is found significant at 5% level with a p value of 0.001 (Table 6.2). Pearson r-value of this relationship is 0.6, showing that there is a strong positive correlation between PM10 and RH with a large effect size. As RH increases, PM10 is expected to increase, and vice versa. Additionally, an increase of 0.0120 units in RH causes an increase of 1 unit in PM10.

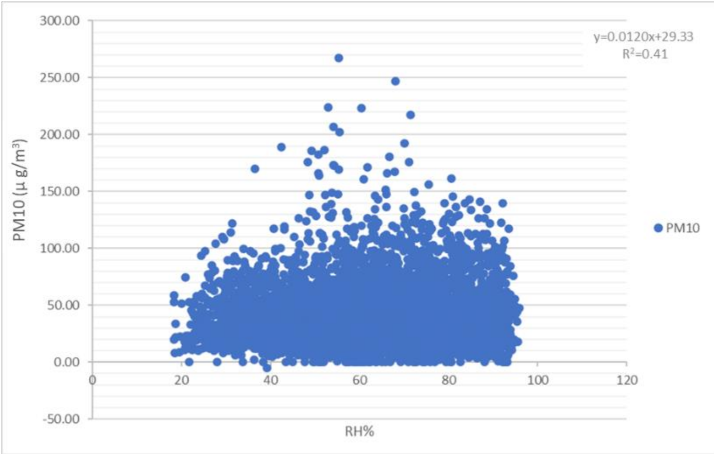

Figure 6.8. Changes in PM10 with RH (Vilayetler Evi).

Looking at Figure 6.10, which shows the relationship of monthly PM10 averages at all stations with RH, the monthly average of RH is at its maximum level in winter.

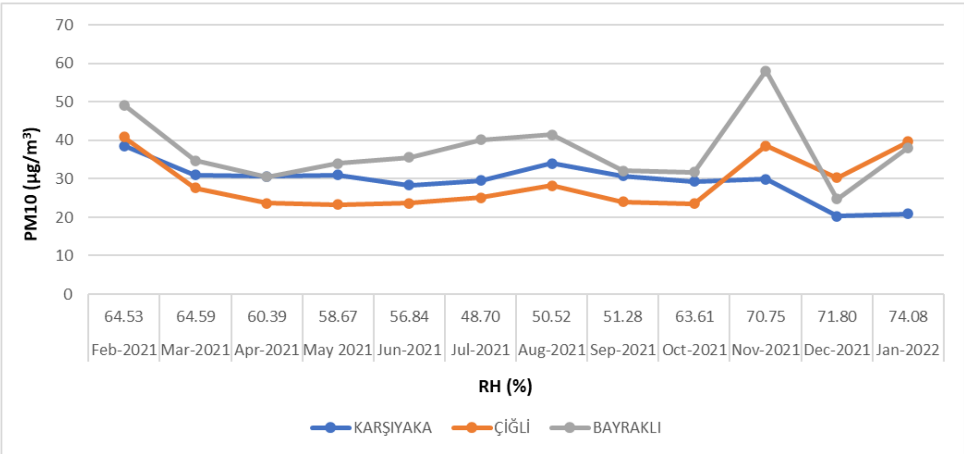

Figure 6.9. Changes in monthly PM10 concentrations with RH for each stations (Vilayetler Evi).

According to Table 6.4, the highest R^2 is encountered for the relation between PM10 and RH. Because PM10 diffuses later than expected as the amount of moisture in the atmosphere increases. Moreover, poor quality (high moisture) fuels may be used for heating purposes during the winter months. According to the results of the individual analyses, 41% of the variation in PM10 is explained by RH. Likewise, 27% of the variation is explained by WS, and 37% by WD. T has been found to explain 11% of the variation but the relationship is insignificant.

Following the linear regression, to examine the effects of independent variables, a multivariable nonlinear regression analysis is chosen and Equation 3 is obtained.

$$PM10 = 2.15998*WD^{0.355894} – 0.83072*WS^{-0.967422} + 1.9638*T^{0.00298} + 1.2927*RH^{0.8392} + 1984.7 \quad (3)$$

As a result, the R^2 value was found to be 0.19. The variability in PM10 was not further explained in the multivariable nonlinear regression with four independent variables.

6.2. Sasalı Natural Life Park

All steps are also performed for Sasalı Natural Life Park data. After conducting one tailed t-test, p-value was calculated. The t- and p-values calculated for statistical significance are given in Table 6.5. Based on Table 6.5, the relationship between PM10 and the WS is found significant at level 1% with the p value of 0.005. Also, analyses of effect size are given in Table 6.6. Pearson r-value is -0.41 showing that there is a significant negative relationship between PM10 and WS with a low effect size. Two variables move in opposite direction, meaning as WS increases, PM10 is expected to decrease and vice versa.

Table 6.5. Evaluation results for Sasalı.

Input	t-value	p-value
WS (m/s)	2.11	0.005*
T (°C)	0.02	0.761NS
WD (Ø)	2.76	0.001*
RH (%)	3.01	0.001*
*= significant at 1% level, **=significant at 5% level, NS= not significant		

Table 6.6. Analyses of effect size for Sasalı.

Input	Effect Size (Pearson r-value)
WS (m/s)	-0.41
T (°C)	Null hypothesis was accepted

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Table 6.6 (cont.)

WD (Ø)	0.46
RH (%)	0.7

Linear regression results are given in Table 6.7. According to the table, the equation is PM10 = -1.753WS + 41.19 where WS is an independent variable, and it is understood from the coefficient in the equation that there is a negative relationship between WS and PM10. A decrease of 1.753 units in WS causes an increase of 1 unit in PM10. Figure 6.11 illustrates the change of PM10 with WS.

Table 6.7. Linear regression results for Sasalı.

PM10 versus parameters	**Equation**	**R^2 value**
WS	-1.753x+41.19	0.38
T	0.0493x+31.8	0.46
WD	0.0461x+39.32	0.21
RH%	0.1189x+32.64	0.51

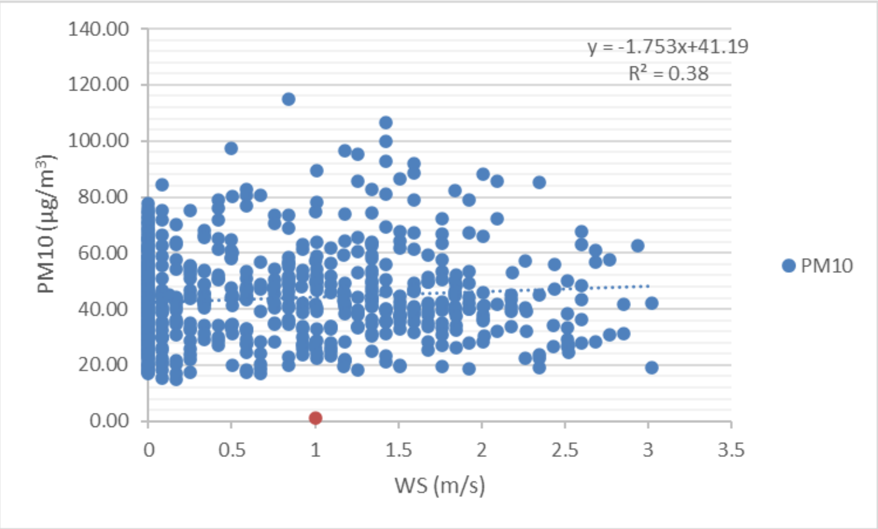

Figure 6.10. Changes in PM10 with WS (Sasalı).

Figure 6.12 shows the relationship between WS measurements taken from the meteorological station in Sasalı and monthly PM10 concentrations at Karşıyaka, Çiğli and Bayraklı air quality monitoring stations. As seen in Figure 6.12, WS is low in winter months when pollution is most prevalent.

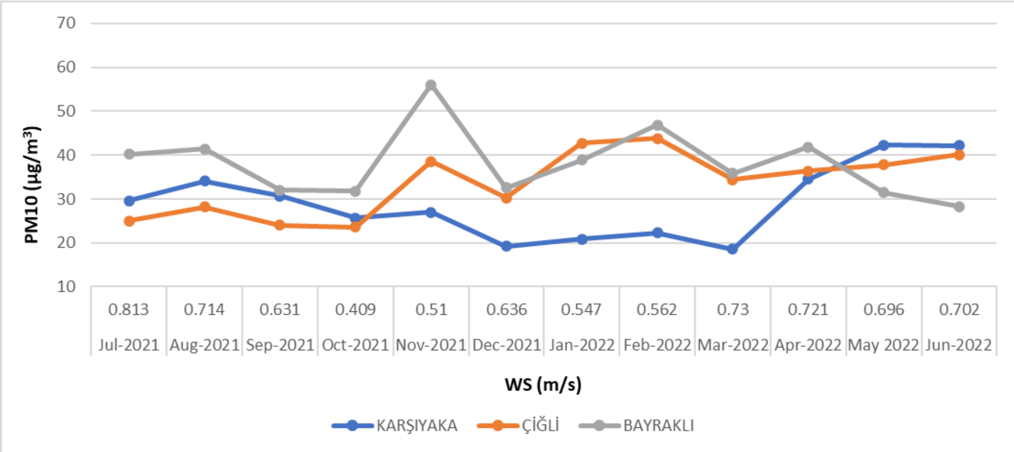

Figure 6.11. Changes in monthly PM10 concentrations with WS for each stations (Sasalı).

Figure 6.13 shows the variation of PM10 depending on T. According to this figure, there is no significant correlation found between PM10 and T. For reference, the graph of change of T according to monthly PM10 concentrations in all three stations is given in Figure 6.14. According to Table 6.7, considering the relationship between PM10 and T, an increase of 0.0461 units in T causes an increase of 1 unit in PM10.

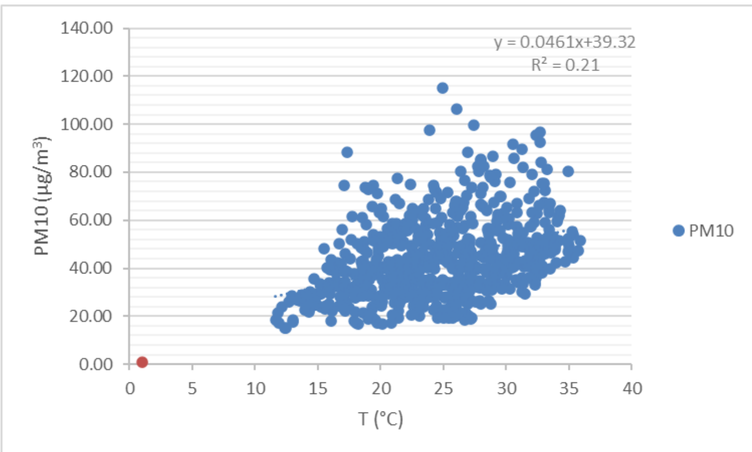

Figure 6.12. Changes in PM10 with T (Sasalı).

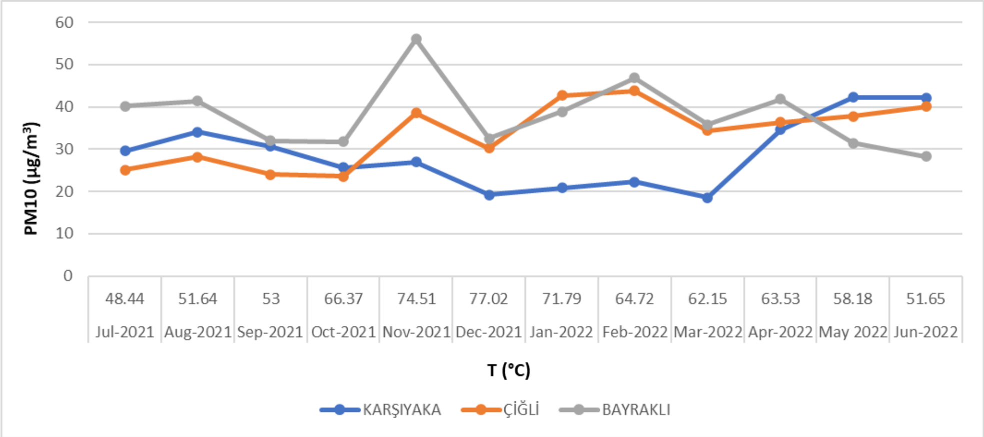

Figure 6.13. Changes in monthly PM10 concentrations with T for each station (Sasalı).

Figure 6.15 shows the variation of PM10 depending on WD. According to Table 6.5, there is a positive significant correlation between WD and PM10 at 1% level with p value of 0.001. Based on Table 6.7, the Pearson r-value of this correlation is 0.46, which shows that there is a moderate relationship between the two variables. Based on this result, it can be said that the variables move in the same direction.

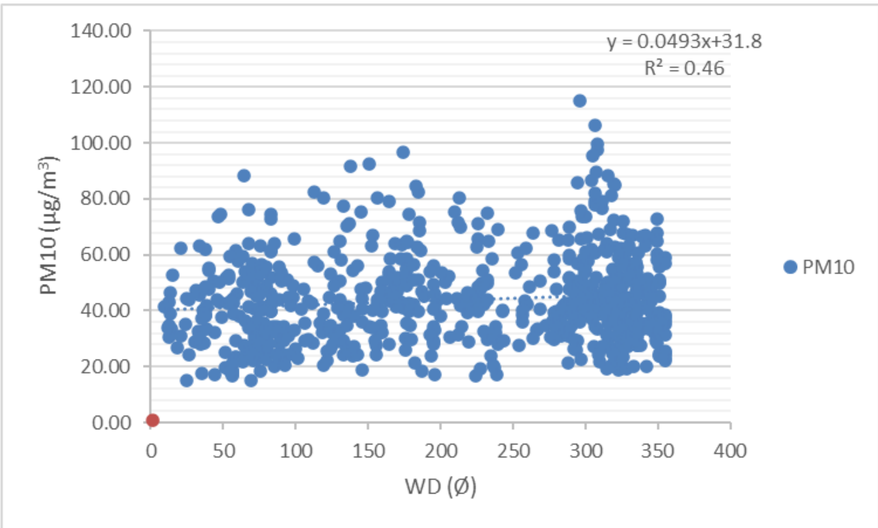

Figure 6.14. Changes in PM10 with WD (Sasalı).

Based on Table 6.5, the relationship between PM10 and RH is found significant at 1% level with a p value of 0.001. According to Table 6.6, Pearson r-value of this relationship is 0.7, showing that there is a strong positive correlation between PM10 and RH with a large effect size. As RH increases, PM10 is expected to increase, and vice versa. Figure 6.16 illustrates how PM10 change as RH% shows different values. Additionally, an increase of 0.1189 units in RH causes an increase of 1 unit in PM10.

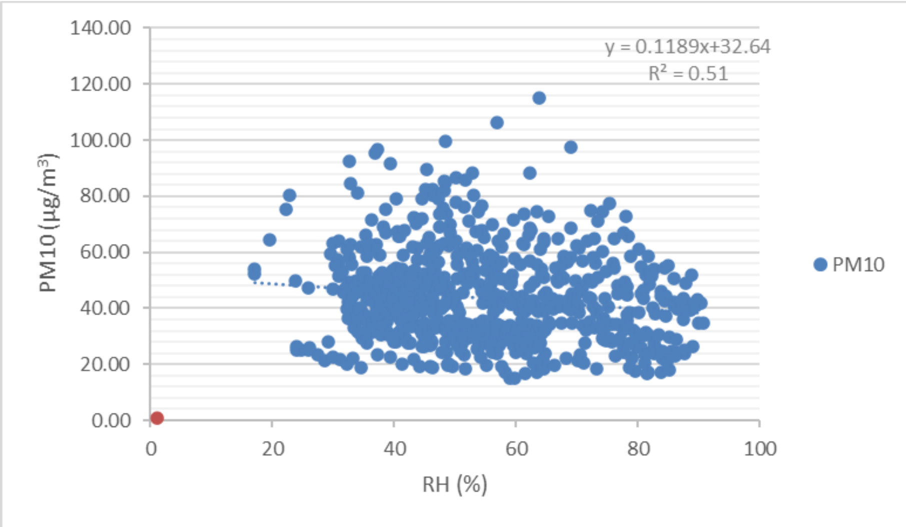

Figure 6.15. Changes in PM10 with RH (Sasalı).

As seen in Figure 6.17, which is the graph showing the change of RH with PM10, the monthly average of RH is at its maximum in winter.

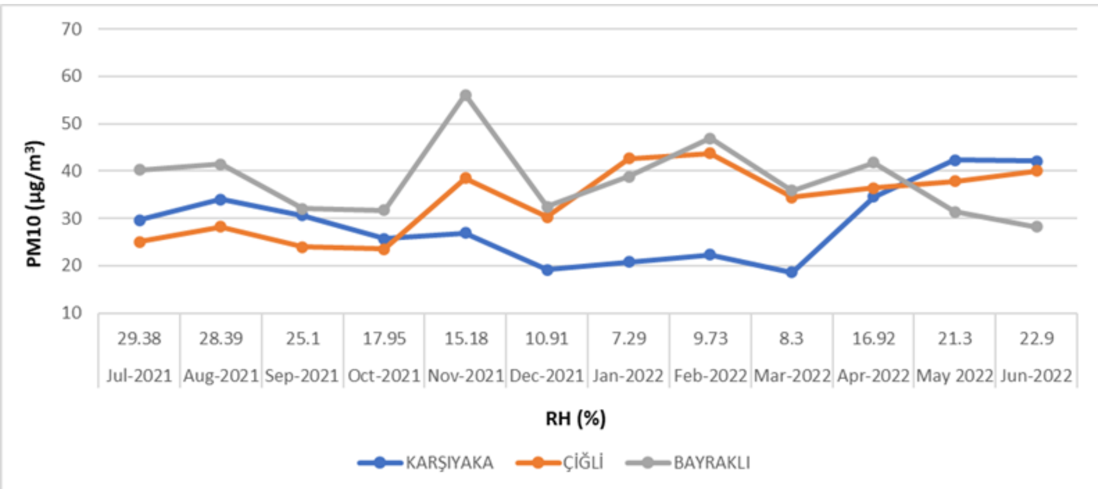

Figure 6.16. Changes in monthly PM10 concentrations with RH for each stations (Sasalı)

As Table 6.7 shows WS explains 38 % variation in PM10, WD explains 46 % variation in PM10 and RH explains 51% of variation in PM10. T has found to explain

11% of variation but the relationship was insignificant. These results show that RH explains the highest variation in PM10. Findings confirm the correlation analysis results. RH has the highest relationship degree and the highest amount of variation in PM10 is due to RH.

Following the linear regression, to examine the effects of independent variables, a multivariable nonlinear regression analysis was chosen to be performed. The equation obtained by this analysis is given in Equation 4.

$$PM10 = 0.252159*WD^{1.0412} - 5.6703*WS^{1.68253} + 0.177812*T^{1.24962} + 1.476*RH^{0.0021} - 1548.18 \quad (4)$$

As a result, the R^2 value was found to be 0.33. Accordingly, WS, WD, and RH explain the variability in PM10 better individually. The variability in PM10 was not further explained in the multivariable nonlinear regression with four independent variables.

When the results of the Vilayetler Evi Hotel and Sasalı Natural Park Life are compared for each independent parameter, it is seen that similar results are obtained. No significant relationship is found between T and PM10 in Vilayetler Evi Hotel and Sasalı Natural Park Life. The effects of WS, WD and RH variables are greater in Sasalı Natural Life Park.

CHAPTER 7

CONCLUSIONS

Development process of İzmir and local resources affect the air quality of the mega city and thus create air pollution. This air pollution has significant impacts on the environment and human health in the short-term and long-term periods. Therefore, it is very important to conduct concentration analyzes and examine the effects of pollutant sources in the areas where the pollution is intense. In this study, the relationship of the PM10 pollutant with meteorological factors was investigated. PM10 data for the period between 2017-2021 was obtained from three air quality monitoring stations (Karşıyaka, Çiğli, Bayraklı) in İzmir province. In the data analysis section, hypotheses were established to determine statistical significance. These hypotheses were tested by one-tailed t-test and p-values were checked. After the statistical significance was determined, the effect size was measured to understand the practical significance. The Pearson correlation coefficient was used for effect size. R^2 was also calculated to determine the strength of the relationship between the variables. When the correlation between PM10 air pollutant and meteorological parameters were evaluated, the highest correlation was found in RH. There was no significant relationship between T and PM10. The analysis results for both locations consistently showed that the order of importance is, from most to least, RH, WD, and WS.

Chemical reactions in the atmosphere are affected by meteorological conditions such as radiation, temperature, and humidity. It is known that urban air pollutants are related to the geographical, geological and meteorological conditions of the cities. In this study, the relationship between PM10 and meteorological parameters was observed. It is necessary to regularly monitor the amount of atmospheric air pollutants to find out more vulnerable areas in cities. Unplanned urbanization reduces the wind transport of pollutants released into the city atmosphere and causes the released pollutants to accumulate in this atmosphere. In city planning, it is of great benefit to build the streets and roads in accordance with the prevailing wind directions and to avoid tall buildings that may affect the wind speed and direction.

In addition to the thermal insulation requirement, the buildings built within the scope of urban transformation should also be required to be a Green Building that produces its own energy. With incentives and contributions, this obligation can be realized as a Renewable Energy Resources Project in low-income districts that are using coal for heating. Falling within the regulations of Unlicensed Solar Energy Generation allowances of up to 10 kW currently in effect, solar power plants can be installed on the roofs of houses in these districts. In terms of environmental and air pollution, natural gas, which is used as a cleaner but non-renewable energy source instead of coal, is nearing expiration. Thanks to the regulations, the number of apartments in cities that meet their electricity needs from wind and solar energy is increasing daily. Furthermore, solar tiles, which offer a clean production opportunity by converting the energy from the sun to electrical energy, have started to be an alternative solution to photovoltaic panels.

Concepts such as global warming, environmental pollution and sustainability have made the automotive industry take action. Electric vehicles have become popular in the last few years, replacing vehicles with engines running on fossil fuels. Municipalities have also started to gradually switch to electric vehicles. Individual vehicle use should be reduced and using public transportation should be encouraged.

In conclusion, considering that fossil resources such as natural gas, oil and coal will be depleted in the next 100 years and, most importantly, all the damage they have caused to the environment, the importance of renewable energy sources is obvious. The relationship between energy and environment is now the most fundamental agenda of the world and studies on this subject will continue until the end of life.

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