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# Determination and modelling of PM2.5 level in summer time in Selcuk University Shopping Centre Konya, Turkey

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**Abstract**

Most of the people spend their most more the time in closed environments during their life. The quality of living atmosphere is really important because of this long contact time period. In inhaled respiration air is contain particle matters pollutant sources in the atmospheric environment, like volatile organic compounds, dusts and different sizes of particulate matters. The health impact of these substances has been investigated in recent years on may scientifically research. In this investigation, particulate matter PM2.5 size dimension, which is one of the indoor air pollutants, was carried out in Selcuk University public shopping center and the data were compared according to seasons, weekday and weekends. For the preparing 3-dimensional mapping, Surfer v.16 computer packed program was used and data modelling was investigated. Certain intervals were measured during three seasons. The measured shopping center is located in the Alaeddin Keykubat campus of Selcuk University. Measurement PM2.5 values in the center of Gökkuşağı shopping center exceed the standards of WHO, and it was observed that summer values were lower than winter seasons. Higher values were observed in the winter season. In terms of measurement area, higher PM concentrations were found in Gökkuşağı shopping center than in similar shopping malls.

## 1. Introduction

Many of the epidemiological studies on particulate matter in the world have shown that the high air pollution caused by these substances, respiratory tract diseases, cardio vascular system and lung problems are great importance on human health [1]. The fact that people generally spend about 90% of their time indoors is clear how important the air quality of these environments is. However, most of the studies to determine the amount of particulate matter in the world have been carried out outdoors, and the studies carried out in closed environments are limited [2]. Particulate matter, which is a mixture of organic and inorganic compounds, is defined as an important source of air pollution. These particles, which are generally divided into two groups in terms of mass; defined as coarse particles (above 10 µm) and fine particles (below 2.5 µm). The residence time of the particles in the air depends on the particle size, the smaller the size of the particles, the longer the residence time in the air [3].

While coarse particles (>2.5 µm) are mostly formed as a result of mechanical processes, fine particles (<2.5 µm, PM2.5) and ultrafine particles (<0.1 µm) can also be formed as a secondary pollutant as a result of chemical reactions of gases and fuels, for example diesel. It is the direct discharge of fuels to the environment as a result of combustion [4]. Concentration levels of indoor particles, the main source of which are activities in indoor environments and outdoor pollution, generally vary due to factors such as the change rate of air, indoor activities, outdoor PM level, aerodynamic diameters of particles released into the environment [5]. Smoking, ventilation mechanisms, heating, cooking and other indoor activities in indoor environments can cause the dispersion of dusts and particles in the indoor environment. When the activities that can cause the dispersion of these particles do not occur, normal activities of people, cleaning activities, moving, skin rashes, dust particles precipitated from fabric and paper fibres may cause the dispersal of dust particles to the environment again [6]. Today, due to the prevalence of research on air pollution and the health problems it causes, it is carried out with the data of outdoor air quality. However, since people spend 87% of their time indoors and these environments have poor air quality, indoor data should be examined instead of outdoor data in order to evaluate the impact of the air in the environment on health.

It is expressed as the air contained in buildings such as workplaces, residences, shopping and living centres, interior spaces of transportation vehicles (bus, car, ship, train, etc.), schools and offices indoor air. Indoor air pollution is the presence of substances that can harm health in the above-mentioned environments. The amount and concentration of these substances in the environment differ according to the characteristics of the environment, the building and interior materials used in the construction of the building, and the behaviour of the individuals in it. For example, the increase in dust and particulate matter rates in the corridors caused by the movements of the students in a school building, as well as the equipment such as printing machine and photocopying machine used in a stationery shop, caused the spread of various volatile organic compounds to the environment. It is a known fact that human performance is affected by indoor air quality. For human comfort and productivity, the indoor environment must be at 19-20°C and the humidity of the air he breathes must be 30-50% [7].

The presence of pollutants in the air by being directly discharged from the source to the atmosphere is called primary particles. Volcanic, soil dust, particles detached from leaf surfaces are all natural main sources of primary particles. Steam generators, traffic, construction and agricultural activities, heating processes are anthropogenic sources. Particles smaller than 1 μm in diameter are usually formed from combustion sources, while particles larger than 1 μm in diameter are formed from natural sources. Secondary particles are the particles formed as a result of the condensation of the primary particles dispersed in the atmosphere with other species in the air, adsorption to the surface and some reactions.

$PM_{2.5}$ exposure threshold has not been defined to provide an unequivocally safe and complete level of protection against all adverse health effects [8]. However, in order to limit the health effects of fine particle pollution, the World Health Organization (WHO) has proposed guidelines for annual and short-term (24 hours) human exposure to PM2.5. In addition to these global standards, WHO encourages governments to define and implement national standards [9]. Along with the guideline levels, WHO has defined three intermediate exposure levels to gradually reduce PM2.5 concentrations. In addition, WHO recommends an annual average, with priority over the 24-hour average, as high $PM_{2.5}$ events are generally less harmful than annual exposure to high PM2.5 levels. The current WHO's annual average air quality guide (AQG) is 10 μg/m$^3$. Australia and the Canadian province of British Columbia are national jurisdictions that introduced a lower standard of 8 μg/m$^3$ [10, 11].

## 2. Material and Method

The variation of the levels of air pollutant concentrations between regions in big cities is shaped by the characteristics of the regions [12]. In this study, which was started on the basis of shopping centres located in Selçuklu district of Konya province, it was chosen as the appropriate location for measurements. This place, which was chosen by paying attention to its indoor environment, is located on the campus of Selcuk University.

Social facilities serving students and staff in Selçuk University Alâeddin Keykubat Campus were deemed suitable as a location for carrying out measurements and collecting data. Rainbow is located in front of the medical faculty, approximately 400 meters from the campus entrance. This building, which covers an area of approximately 13000 m$^2$, consists of 63 stores, stationery, bookstores and restaurants.

In the northern part of the building, there are two corridors with a width of approximately 2 m on the east and west sides, and the entrances of some shops are within those corridors, the air pollutants circulating in these corridors, which consist of low ceilings, are trapped in a narrow area, causing them to be close to the respiratory level.

Although the shops have their own ventilation systems, they are not available in the common areas. As a result of the fact that the areas with an air blowing system were out of use due to technical failures, a suspended ceiling was built and completely closed. Although the Gökkuşağı shopping center, which was built and put into operation in 1999, underwent simple renovations over time, no general restoration was carried out from its opening to the working period. 13 points were determined for the measurements to be made in the rainbow (Figure 1).


**Figure 1.** Selcuk University Alaeddin Keykubat Campus Gökkuşağı shopping centre sampling points (edited from [13])

### 2.1. Particulate matter meter measurement device

The measurement methods of dust and particles in the air vary according to the volume of the particles and the desired results in the study. Thanks to electronic recording, the data can be displayed numerically in a laser particle counter and dust measuring device "Particle Counter PCE-PCO1" configured to determine the concentration of particles in the air. This device is used in clean rooms, indoor air quality, exposure to exhaust, tobacco or cigarette smoke and other harmful air pollutants, and for monitoring airborne dust levels.

The particle counter was developed to precisely determine the pollution level. The device measures 6 different particle sizes (0.3 µm, 0.5 µm, 1.0 µm, 2.5 µm, 5.0 µm, 10 µm), measurements (more than 5000 measurements) can be saved in the internal memory, A large colour LCD with backlight, for image and video recording other features include a built-in camera, air temperature, dew point and relative humidity sensors, displaying the temperature in °C or °F. This device, which is deemed suitable for taking measurements at different points in terms of its easy portability, should be charged and prepared before going to the measurement site and zeroed by calibration in a dust-free standard environment before measurement.

The device also has 3 different sampling modes: cumulative, differential (differential) and concentration. The desired mode must be selected before measuring. In addition to these features, the date and time, language and screen brightness can be adjusted optionally from the system settings. In these studies, it is of great importance that the data obtained depending on the sampling and measurement period are constantly (if possible, daily checked) from the memory card of the device to the computer environment in order to avoid data loss.

### 2.2. Modelling and graphics program Surfer-16

This software, produced by Golden software company, consists of a 3D graphics system. It is used for gridding scattered data recorded in different environments, creating contour maps and obtaining 3D images [14]. Since 1984, more than 100,000 scientists and engineers worldwide have benefited from Surfer. The program's exceptional shaping capabilities make it the preferred software for working with X,Y,Z data. It shows high performance to visualize X,Y,Z data with stunning clarity and accuracy. This program, which transforms the collected data into information, visualizes the data in high quality while preserving its accuracy and precision. Along with Surfer's extensive modelling tools, interpolation and grating parameters can be adjusted, define errors and breaks, or perform grid calculations such as volumes, transformations, smoothing or filtering [15].

It consists of map types such as contour, calculation, 3D surfaces, colour relief, etc., and provides tools to visualize and model all types of data. The type of map obtained in this study is contour map. After making all the statistical calculations by turning the 3D data loaded on the worksheet into a grid, the map is created by selecting the desired map type. In order to make the map more meaningful and readable, the map can be personalized with various customization options, thanks to the window in the lower left corner of the screen. These options include sections, magnifiers, scale bars and edits such as multi-axis, linear or logarithmic color scales, combining multiple maps, text, line, fill, and symbol properties [15].

### 2.3. Particulate matter PM2.5 measurement method

In the researches carried out to determine the particulate matter concentrations, the pollutant sources in the external environment were examined. By comparison, there is little information on indoor particulate matter pollution, its concentrations, sources, and exposure levels to people who spend most of their time in various indoor environments [16]. In this study, which was started to determine the effect of seasonal changes on particulate matter, summer, autumn and winter seasons were selected to take measurements, and two-day measurements were made on weekdays and weekends. The total measurement period was completed as 4 days in each period.

In all three seasons when the measurements were made, the daily measurement program lasted for 10 hours, depending on the working hours of the venues. Measurements were repeated 6 times a day with an interval of 2 hours. After taking the coordinates of the measurement points, the data collected at the end of each season are listed in the Excel program in such a way that daily, weekly and hourly averages are taken. X and Y coordinates and Z coordinate represented the measured $PM_{2.5}$ values. A worksheet was created by transferring X,Y coordinates and measurement values to the SURFER-16 program. Statistical calculations were made by converting the prepared data into tables. Then, contour map is selected from the map options in order to show the contour lines. The customization window is used to clearly show high and low concentrations and dispersion lines on the map.

## 3. Results and Discussion

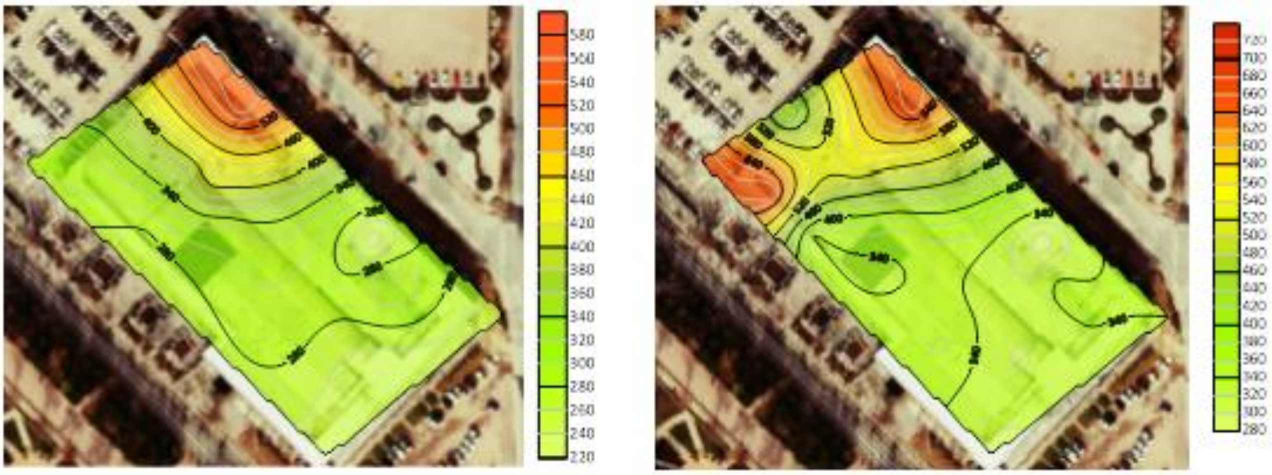
Particulate matter measurements were carried out in three different seasons in the rainbow shopping center of Selçuk University Alaeddin Keykubat campus, an important shopping center in Konya. The sampling period was carried out between 21.05.2018 - 03.06.2018. During the measurement periods, measurements were made for one week. Weekly average distributions of particulate matter PM2.5 were prepared with Surfer 16 by measuring 6 times a day.

Within the scope of the research, it was arranged to be close to the opening and closing hours of the shopping center between the hours of weekdays and weekends (09.00 - 19.00). As a result of the study, the average values of PM2.5 obtained from the examination of all data during the week and at the weekend are shown in Table 1.

**Table 1.** This is the example of table formatting

| Sampling period | Weekday average $PM_{2.5}$ µg/m$^3$ | Weekend average $PM_{2.5}$ µg/m$^3$ |
|---|---|---|
| Summer | 600 | 528 |

According to the summer period data, the average of PM2,5 at 9:00 in the morning was 580 µg/m$^3$ on weekdays and 720 µg/m$^3$ on weekends. While the most intense point of pollution was at point B on weekdays, it was seen intensely at points B and C on weekends. point B; it is in a narrow and closed corridor with cooking stoves, hairdressers, tailors and locksmiths. Thanks to these shops that are actively working, there is not much difference between weekday and weekend values. Point C, on the other hand, corresponds to the aforementioned corridor in the shopping mall, on the west side of the building. There is a restaurant material entrance area, a medical equipment sales point and a clothing store door opening to this corridor. The value seen over the weekend appears to have increased due to the material loading in the corridor. The modelling results are shown in Figure 2.

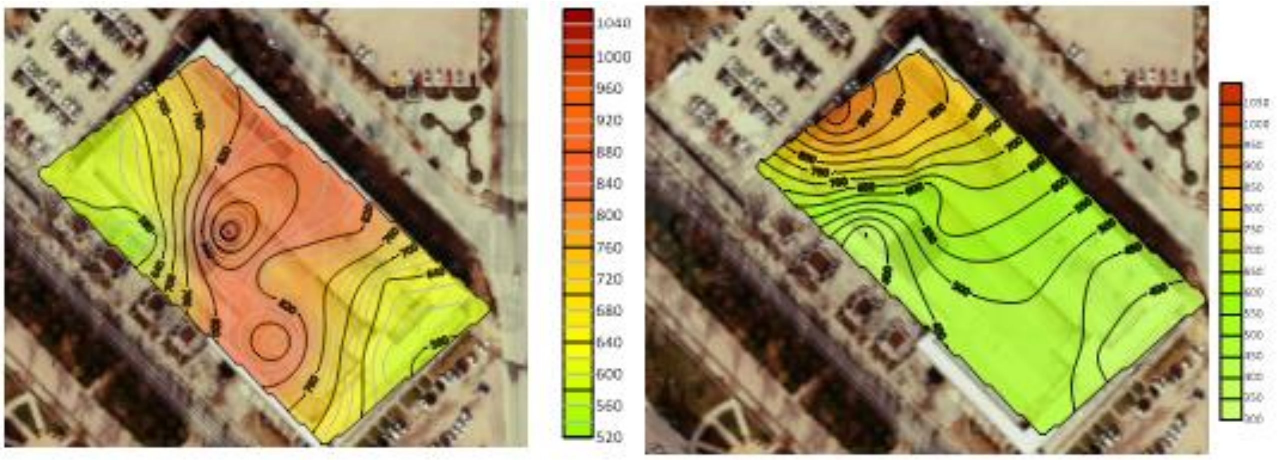



**a.** **b.**

**Figure 2.** Summer season at Gökkuşağı Mall at 9:00 a.m. a-Weekdays, b-Weekend average

As the middle of the day approaches, the values increase slightly and the measurements made around 11:00 reflect the modelling in both weekday and weekend averages. The average of $PM_{2.5}$ at 11 o'clock was found to be 1040 µg/m$^3$ on weekdays, and very close values were obtained as 1050 µg/m$^3$ at the end of the week. The intense pollution zone seen on weekdays exactly coincides with the middle parts of the building, some of the corridors and restaurants (Figure 3).

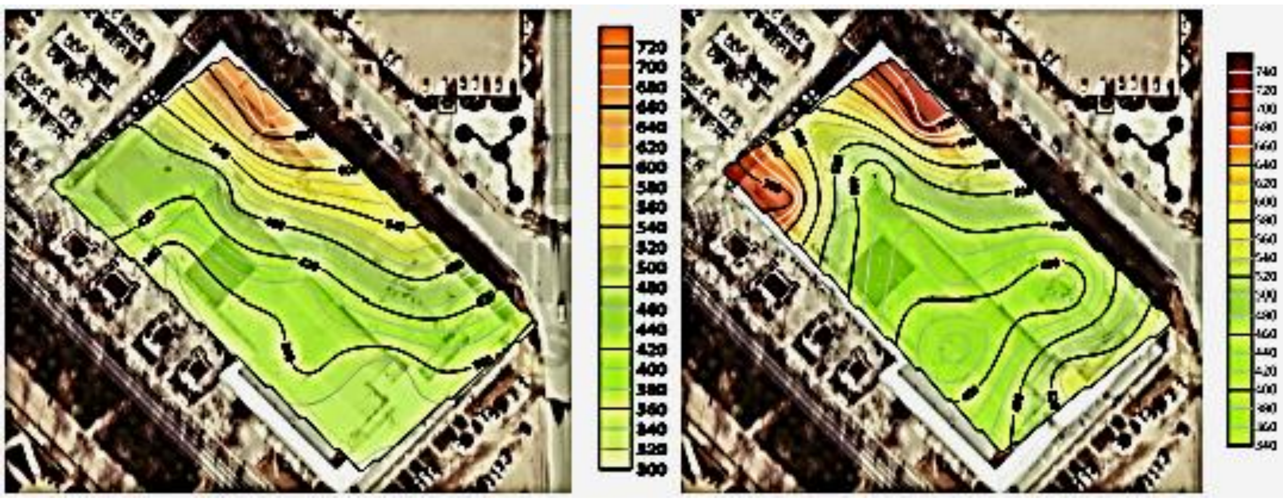
With the campus staff and students taking a lunch break around this time, the number of people inside the Rainbow Shopping Centre increases significantly. In this time period, $PM_{2.5}$ concentration also increases in direct proportion to the increase in the number of people. $PM_{2.5}$ is higher than weekdays, but $PM_{2.5}$ is higher at the weekend. A. This spot is located at the north entrance of the building and is mostly open. Other parts of the building have normal $PM_{2.5}$ values, and it is thought to be high in the north door entrance and $PM_{2.5}$ as a source of pollutants originating outside. Modelling results for 11:00 am measurements are shown in Figure 3.




**a.** **b.**

**Figure 3.** Summer season at Gökkuşağı Mall at 11:00 am. (**a**-Weekdays, **b**-Weekend average)

The high values of the weekend compared to the weekdays gave similar results at the average of 13:00. Weekday average was 720 μg/m³ and weekend average was 740 μg/m³. As a result of the dispersal of the majority (students and school personnel) who entered the shopping mall after the lunch break time was over, a decrease was observed in the values of $PM_{2.5}$ in the indoor environment. In addition, it causes $PM_{2.5}$ dilution in the indoor environment due to the ventilation activities carried out by doors and windows in the indoor environments in summer. The results at time 13.00 are shown in Figure 4.

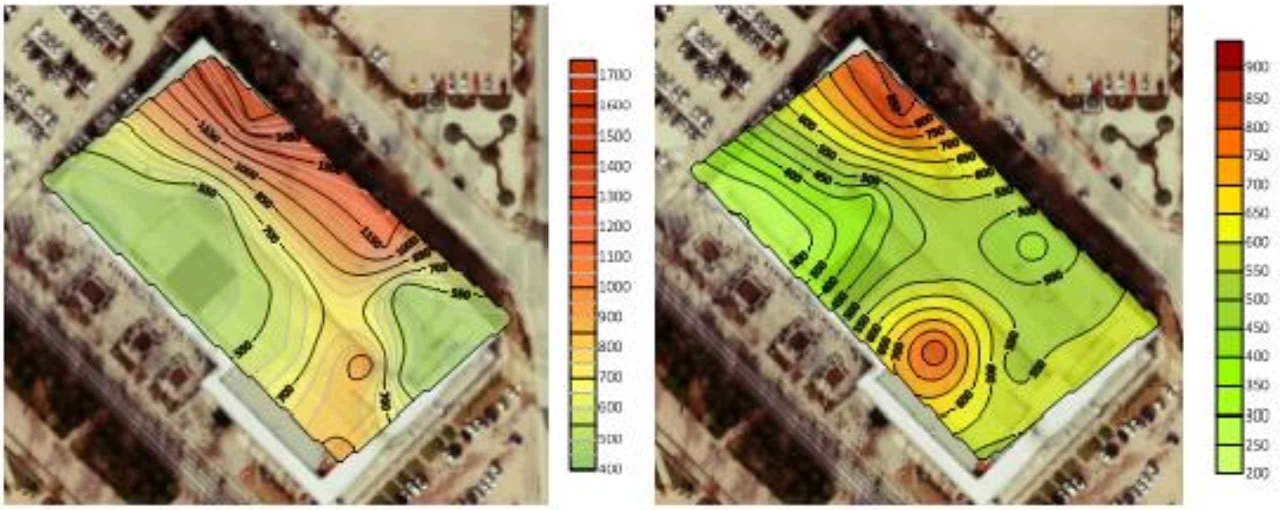


**a.** **b.**

**Figure 4.** Summer season at Gökkuşağı Mall at 13:00 (**a**-Weekdays, **b**-Weekend average)

The average of 15.00 μg/m³ on weekdays during the summer period was found to be 1700 μg/m³, when we look at the $PM_{2.5}$ values, $PM_{2.5}$ concentrations between 900-1,700 μg/m³ along the B, F, G, H, I, J, K points correspond to the end of working hours. This indicates an increase in the number of visitors and a crowd in the shopping mall. This is especially true where these points (corridors and dining areas) are located. As the crowd increases in closed environments, there is an increase in particulate matter in direct proportion. This is a situation that can be seen even in the case of ventilation in the summer season. As the human activity rate increases, PM2.5 concentrations increase.

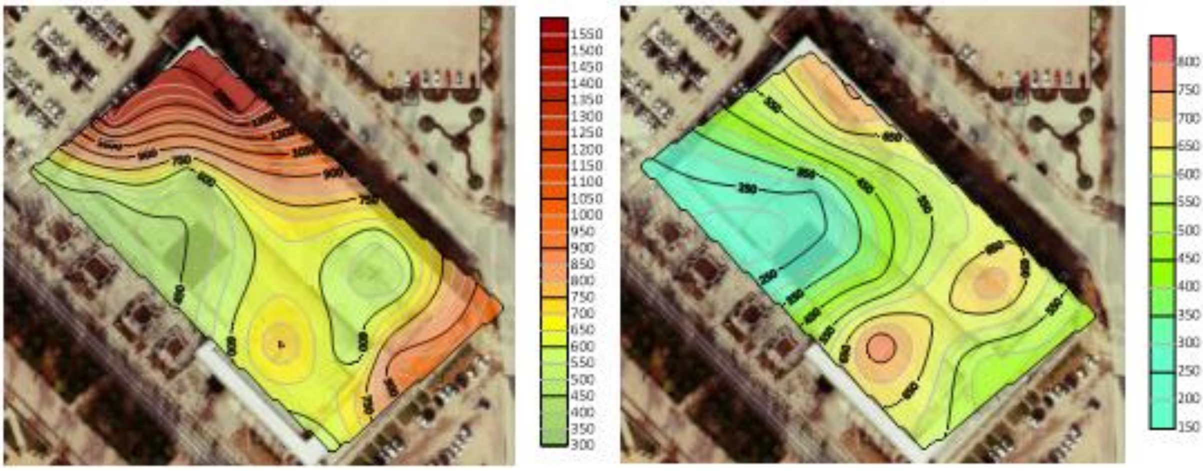
Weekend $PM_{2.5}$ results were 900 µg/m$^3$, half the weekday average. Although the points where the values are high are the same, the concentration of particulate matter is lower due to the decrease in the number of visits to the shopping mall after 15:00 on the weekend. The results at 3:00 PM are shown in Figure 5.




**a.** **b.**

**Figure 5.** Summer season at Gökkuşağı Mall at 3:00 pm (a-Weekdays, b-Weekend average)

In general, point B of the rainbow with the highest $PM_{2.5}$ value was observed at 17.00 with a high average of 1550 µg/m$^3$ on weekdays. Looking at this result, $PM_{2.5}$ is seen at high values in the north and north east parts of the building. In the western part of the building, a lower value (around 600 µg/m$^3$) was found throughout. The values rising again in the south-easter part of the building indicate the presence of the pollutant source entering the interior with the door open to the outside environment. Along with the decrease in the number of people on the campus towards the evening hours on weekends, the number of people coming to the shopping mall also decreases. It shows that this situation is observed at the weekend values at 17.00 hours and the average concentration decreased to 800 µg/m$^3$. Figure 6 shows the weekday and weekend results at 17:00.

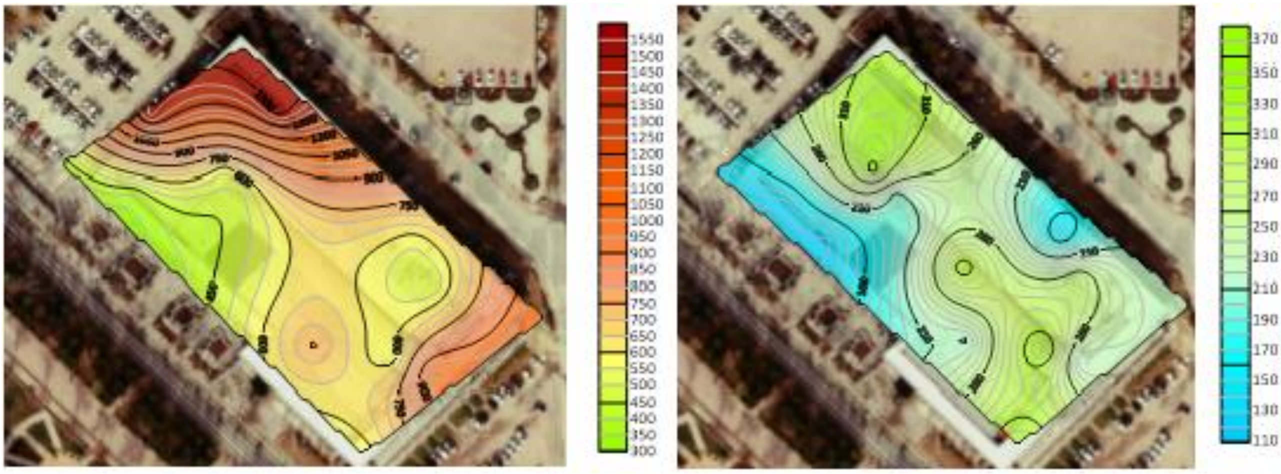



**a.** **b.**

**Figure 6.** Summer season at Gökkuşağı Mall at 5:00 pm (a-Weekdays, b-Weekend average)

$PM_{2.5}$ level at 19.00, when the last measurement of the day was made, was 1,550 µg/m$^3$ on weekdays and 370 µg/m3 on weekends. At 19.00, it coincides with the patient visiting hours of the Selcuk University Medical Faculty Hospital, located on the west side of the Rainbow Mall. With this said, most of the visitors who come to the hospital at that hour stop by the shopping mall for food or shopping. On the contrary, $PM_{2.5}$ level was found to be very low compared to weekdays due to the fact that there were very few people on the campus at the weekend. Figure 7 shows the modelling results of the last measurement at 19:00 in the rainbow shopping mall in summer.

With a general interpretation, as a result of the measurements made in the summer period, the lowest PM2.5 value is 370 µg/m$^3$. This value exceeds the hourly 25 µg/m$^3$ limit set by WHO, EEA and EPA for PM2.5. In the outdoor air quality assessment management and regulation updated in 2008 in Turkey, the standard value for PM2.5 is 200 µg/m$^3$. While the indoor air should be lower than these values, the results obtained exceed the HKDYY limit value.




**a.** **b.**

**Figure 7.** Summer season at Gökkuşağı Mall at 5:00 pm (a-Weekdays, b-Weekend average)

## 4. Conclusion

In this study, indoor air quality, the importance of which has started to be noticed in Turkey in recent years, has been examined. In this study, which was started in Konya, one of the most important industrial cities of the country, based on shopping centers, particulate matter PM2.5 measurements, which carry serious risk factors on human health and which is in the second rank among air pollutants by the World Health Organization, were made. Two different environments were selected for the measurements. Rainbow shopping center located on Selçuk University Alaeddin Keykubat campus was chosen as the first location for measurements. Measurements were made in three separate periods. Sampling was carried out during the summer season between 09:00 and 19:00 between 21.05.2018 – 03.06.2018. When investigated how particulate matter PM2.5 affects indoor air quality throughout the season and what causes it. The results were mapped and modelled using the Surfer 16 program. While modelling, the results were interpreted as weekday and weekend averages. As a result, measurement PM2.5 values in the center of Gökkuşağı Mall did not exceed WHO's standards [17].

It is thought that the fact that the building structure of Gökkuşağı shopping center is older has an effect on the results. In addition, the central ventilation system in the building was not repaired and closed for use years ago as a result of deterioration, resulting in insufficient air circulation inside. Thanks to the stationery, photocopiers, restaurants, clothing, tailors and cafes in the building, there are only 3 exit doors so that the pollutants dispersed in the indoor environment can mix with the outside environment. The number of daily visitors also had an effect on the high values observed especially at noon. In addition to the lack of ventilation, the absence of a ban on smoking caused the corridors in the northern part of the building to be exposed to the highest PM2.5 pollution. It is thought that the old building materials and the unrepaired structure also affect the pollution level. Since the measurements took place on campus, higher values were obtained during the week, except for some exceptional cases. This building, which is located right across the medical faculty hospital in terms of its location, caused an increase in PM2.5 pollution in the shopping mall in direct proportion to the patient visit hours of the hospital.

## 5. Recommendation

In order to breathe healthy air in closed living spaces where people spend most of their time, these environments and existing ventilation systems, devices and vehicles must be maintained by constantly monitoring and controlling in terms of quality atmosphere [18]. For this reason, it is necessary to implement methods that will ensure an acceptable indoor air quality in shopping malls. These methods are respectively;

- Removal of the source affecting the environment,
- Making central ventilation systems according to standards suitable for the environment in which they will be used, using them appropriately and maintaining them at regular intervals,
- It is recommended to take precautions against smoking in closed environments.

Also; universities should organize lectures, symposiums and educational seminars in educational institutions about the importance of indoor air quality and its effects on health. Due to the lack of standards determining indoor air quality in Turkey until today, it is recommended that the relevant institutions take action as soon as possible to establish standard values for this air, which has a direct impact on the health of living things. It should be ensured that the parameters determining the air quality in all provinces of Turkey are measured and modelling maps are created.

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**Author contributions**

**Sukru Dursun:** Conceptualization, Methodology, -Reviewing and Editing; **Mina Naseer Qasım:** Investigation, Data curation, Writing-Original draft preparation, Modelling.

**Conflicts of interest**

The authors declare no conflicts of interest.

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