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$PM_{2.5}$ concentration measurements and mapping at Gokusagı Mall for autumn 2018, in Konya, Turkey

Sukru Dursun [*1], **Mina Naseer Qasım** [1]

[1]*Konya Technical University, Environmental Engineering Department, Konya, Türkiye, sdursun@ktun.edu.tr; mineenviro@gmail.com*

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Abstract

The majority of people living in urban areas spend a significant part of their lives indoors such as homes, schools and workplaces. Therefore, the air quality of indoor or indoor environments is very important. As in Turkey, while improving the outdoor air quality first, regulations on indoor air quality have started to be developed recently, or lower pollutant concentrations are determined by lowering the air quality standards by certain ratios for acceptable limit values for indoor environments. Ventilation systems and air quality are very important especially for Shopping Centers, which are visited by people from different walks of life and have many different business lines. Gökkuşağı Shopping Center also causes thousands of patients and their relatives to visit because of the fact that the Faculty of Medicine has more than 100 personnel, together with around 100 thousand students belonging to Selçuk University. Gökkuşağı Shopping Center, which was established to meet the needs of these people, serves around 100 people with its cafes, restaurants and many workplaces. This service is concentrated at certain hours, especially when there is a need for food. In this study, which was carried out during the university education period, the measurements of the particle size ($PM_{2.5}$) pollution reaching the human lungs and remaining there to a large extent were made at 6 different hours between the opening-closing hours of the shopping mall. The distribution of the pollutant in the space was modelled using the Surfer16 package program and the distribution map was drawn. The values obtained in the measurements were above the international standards.

1. Introduction

Industrialized societies also want a modern living space in modern life and living spaces. These vehicle demands bring along motor vehicles and industrialization close to city centres and this poses a danger to human and environmental health. Gases belonging to air sources, and their life span in nature and nature are important due to their nature. A person breathes an average of 13,000–16,000 litters of air per day, or 400–500 million litters of air in a lifetime. Therefore, clean and polluted air is important for humanity [1]. Among the world climate, one of the world's weathers has been determined in relation to the world climate in 1992. Indoor air circuit from 2 main sources. Designs consisting of interior design and design, interior designs consisting of interior designs.

Indoor PM uses are affected by drinking, cooking, home, etc., first of all, outdoor-indoor atmosphere-indoor ventilation such as resuspension and ventilation, and removal from outdoor-indoor air such as hand precipitation [2-4]. Certain indoor environments in homes are expressed in time, outdoor environments indoor $PM_{2.5}$ levels approximately 75% PM10 levels approximately 66%. Since there are important indoor types in homes, it is understood that the contribution of outdoor air to indoor PM_{10} and $PM_{2.5}$ levels is still around 55-60% [5].

No $PM_{2.5}$ exposure threshold has been defined to provide an unequivocally safe and complete level of protection against all adverse health effects [6]. 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 $PM_{2.5}$. In addition to these global standards, WHO encourages governments to define and implement national standards [7].

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 [8]. 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.

In this study, $PM_{2.5}$ concentrations were measured at different times during the day in the closed environment of the closed social area Gökkuşağı Shopping Centre at Selçuk University, one of the campuses with the highest number of students in Turkey, and three-dimensional pollution maps were obtained by modelling the indoor distribution.

2. Material and Method

2.1. Study area

In this study, which was started on the basis of shopping centres located in Selçuklu district of Konya province, suitable measurement points were determined for making measurements. This place, which was chosen by paying attention to its indoor environment, was chosen as the place where people visit the most on the campus of Selçuk University.

It was carried out in the social facilities that serve students-employees and those who come to the hospital in the Alâeddin Keykubat campus of Selcuk University, and the locations for the data were determined. The details of the study area are given in Naseer Qasim [9].

There are two corridors with a width of approximately 2 m in the north, east and west parts of the shopping centre. Some business entrances lead to these corridors. These corridors, which consist of a ceiling structure that cannot be high as a structure, cause the air pollutants circulating in a narrow area to be trapped in a narrow area and close to the respiratory level.

Although existing workplaces have ventilation systems, they are not sufficient in common areas. In previous years, the air blowing system was out of use due to technical malfunctions. Although the Gökkuşağı Shopping Center, which was built and put into operation in the past years, has undergone simple renovations over time, there has not been sufficient improvement from its opening to the working period. 13 measurement points were determined to represent the space for your measurements in the rainbow (Figure 1).

Figure 1. Selcuk University Alaeddin Keykubat Campus Gökkuşağı shopping centre sampling points [10]

2.2. Atmospheric Particulate Matter Measurement Method

Atmospheric particulate matter measurement methods vary according to the size and purpose of the particles. Thanks to electronic systems, a laser particle counter and dust measuring device "Particle Counter PCE-PCO1"

configured to determine the concentration of particles in the atmosphere can be determined. This device is used in non-polluted environments, indoor air quality or exposure to cigarette smoke and other harmful air pollutants, and for monitoring dust levels in the air. Detailed information for measurement can be obtained from [9] and [11].

In a study conducted by Stranger et al., [12] in 18 homes and 27 schools, it was determined that cigarette smoke was the most effective reason for the presence of $PM_{2.5}$ and PM_{10} pollutants. In the study by Lee *et al*., [13] at 14 different points (restaurants, libraries, shopping malls, gyms, parking lots), it was determined that there are traffic emissions and roads as PM_{10} pollutant sources and this is reflected in the indoor environment. A total of 14 different points were used as indoor environment in the study conducted in. Indoor / outdoor ratios for PM_{10} were found to be due to the high infiltration rate and the presence of indoor air pollutants. The indoor / outdoor ratio for PM_{10} is 4 times higher, respectively, in smoking areas than in non-smoking areas [13]. In the indoor air PM measurements made at a University in Istanbul, measurements were made in the canteen, dean's office, financial office and classrooms. and EPA limit values of 35 $\mu g/m^3$ are only exceeded in the canteen and workshop [14].

2.3. Modelling and graphics program Surfer-16

Golden software 16 is a program capable of modelling and creating a 3D graphic preparation system that includes basic statistics. It is used for creating contour maps and obtaining 3D images by processing complex data obtained from different processes and making grids [15, 16]. Since the eighties, more than 100,000 scientists and engineers around the world This program, which transforms the collected data into information, visualizes the data in high quality while preserving its accuracy and precision [17]. 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 [18].

2.4. Particulate matter $PM_{2.5}$ 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 less information about indoor particulate matter pollution, its concentrations, sources, and exposure levels to people who spend most of their time in various indoor environments [19]. In order to determine the interaction of particulate matter values with seasonal changes, studies are carried out in different seasons to take measurements in the study. In this study, autumn was chosen as the opening period of schools, and in the study, two-day measurement intervals were determined on weekdays and weekends. The periodical measurement period was completed as 4 days.

The daily measurement program, in which the measurements were made, lasted 10 hours depending on the working hours of the places. Measurements were repeated in 6 periods per day with an interval of 2 hours. After the measurement points and coordinates were determined, the final data were collected and the Excel table was arranged and listed in such a way that daily, weekly and hourly averages were taken. X and Y coordinates and Z coordinate represented the measured PM2.5 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 2.5 micro meter size measurements were carried out in the autumn period in the rainbow shopping centre of Selçuk University Alaeddin Keykubat campus, which is one of the important shopping centres in Konya. The sampling period, the second sampling period, was carried out between 24.09.2018 - 07.10.2018. During the measurement period, measurements were made for one week. Weekly average distributions of particulate matter PM2.5 were prepared for Surfer 16 by measuring 6 times a day.

Within the scope of the research, it was arranged to cover the opening and closing hours of the shopping centre between the hours of weekdays and weekends (09.00 - 19.00) at the Gokkusagi AVM at the university. 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. Autumn season weekday and weekend particulate matter PM2.5 averages in Rainbow shopping mall.

Sampling period	Weekday average $PM_{2.5}$ $\mu g/m^3$	Weekend average $PM_{2.5}$ $\mu g/m^3$
autumn	693	496

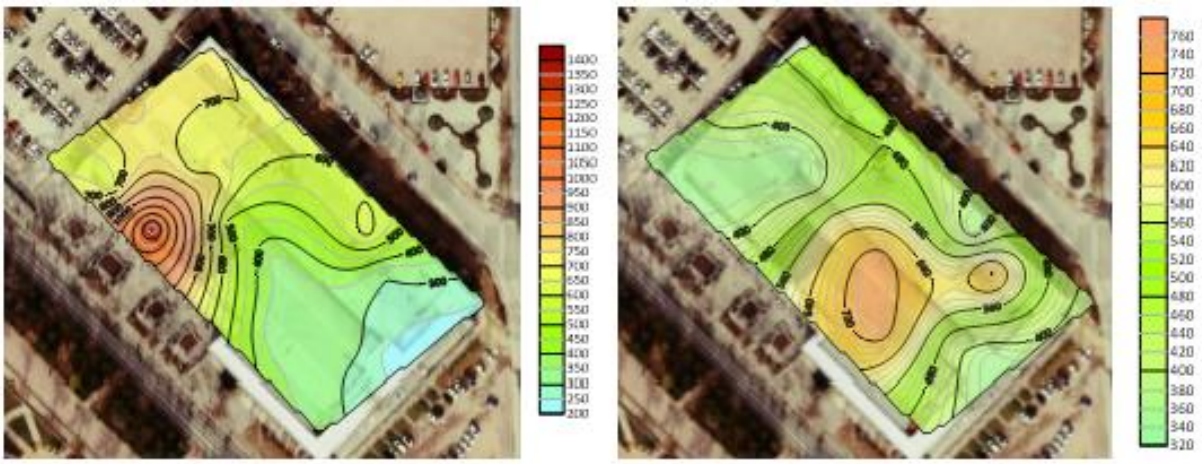
Average $PM_{2.5}$ concentrations in the autumn 2018 period were found to be 693.65 $\mu g/m^3$ and 495.75 $\mu g/m^3$ on weekdays. Measurement times were made between 09.00-19.00 hours. The 7-day measurement period, which started right after the official semester registration of Selçuk University, started on 24.09.2018 and continued until 30.09.2018.

The weekday average was found to be 1400 $\mu g/m^3$ even in the early hours of the day thanks to the pollution that occurred at point F (west entrance gate) and exceeded 1000. It affects the entrance point of the restaurant

chimneys located on both sides of the entrance door. Values not exceeding 700 µg/m³ were observed during weekdays in other parts of Gökkuşağı Shopping Center.

Low PM2.5 concentration was found to be 760 µg/m³, resulting from quieter weekends and fewer visits. The modelling results of the first average PM2.5 concentration of the study period at 09:00 are shown in Figure 2.

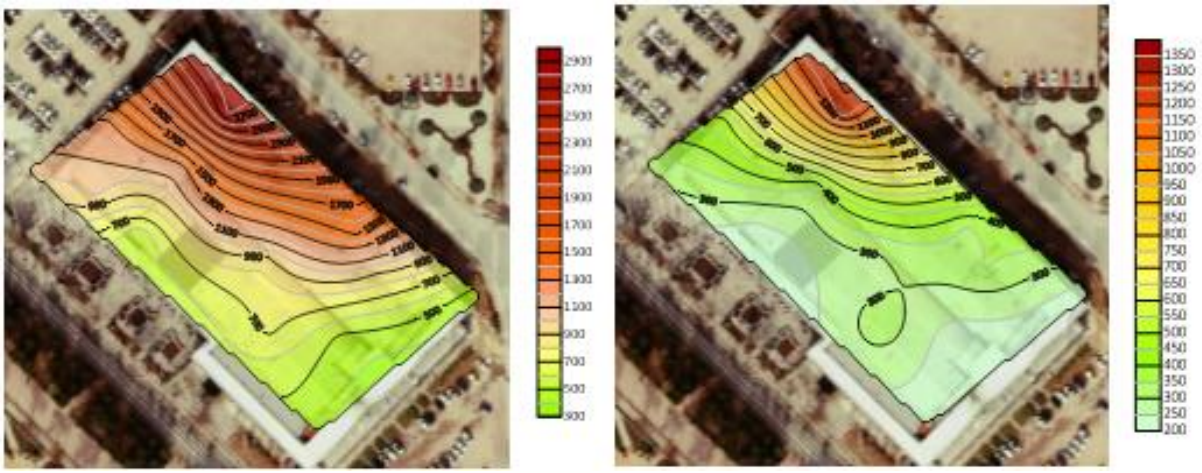
The values at 11:00 am found to be quite high and the PM2.5 value was found to be 2900 µg/m³. Here, the particle pollution formed at point B started from the north-eastern part of Gökkuşağı Shopping Center and spread towards the centre. PM2.5 concentration was found to be at least 1300 µg/m³ at points J and K where cooking restaurants are located. Cooking activities have been ranked 2nd by EPA as the indoor PM2.5 formation source [20].



a. **b.**

Figure 2. Gokkusagi Shopping Center at 9:00 a. Weekdays, b. Weekend average

A comfortable and healthy indoor environment in restaurants increases the visual appearance and protects the health of customers and employees against harmful air pollutants [21]. Weekend Particulate matter pollution is 1350 µg/m³ by showing its effect only at the point where it occurs. In other parts of the mall, concentrations during the weekend did not generally exceed 300-400 µg/m³. Figure 3 shows the modelling results at 11:00.

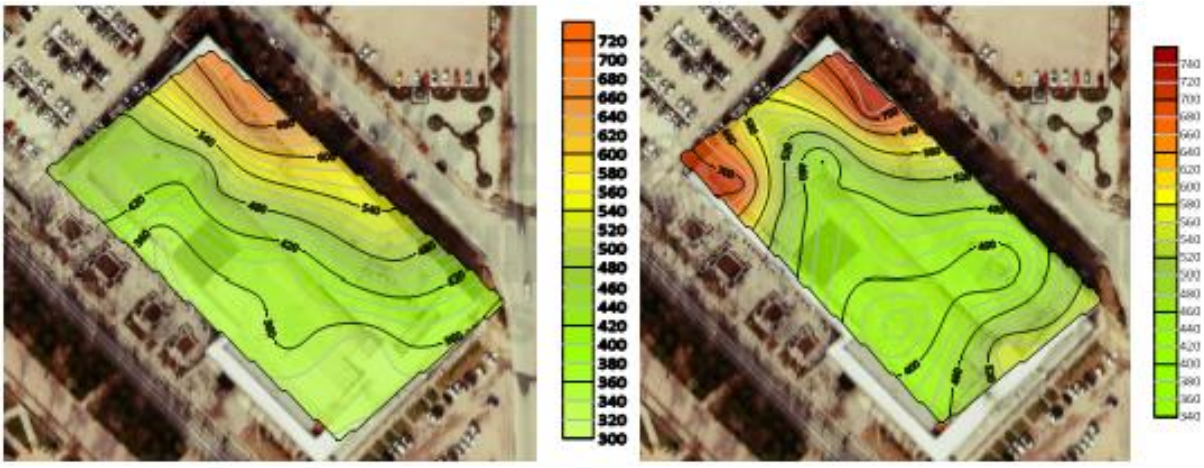


a. **b.**

Figure 3. Gokkusagi Shopping Center at 11:00 a. Weekdays, b. Weekend average

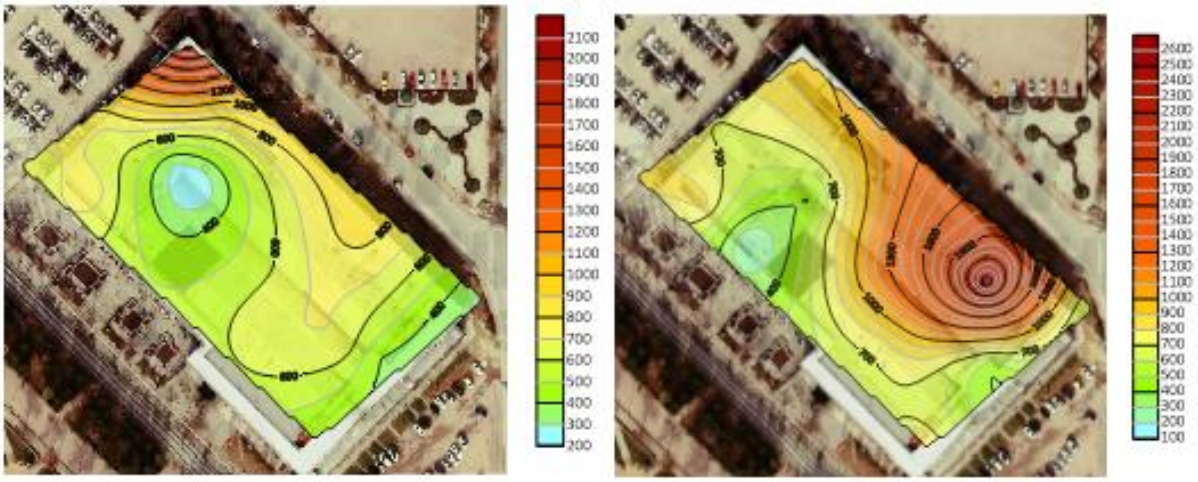
Looking at the pollution map prepared for 13.00, it is seen that the $PM_{2.5}$ concentration shows a similar distribution to 11:00. While values are found as 1300 µg/m³ in the northern part of Gökkuşağı Shopping Center, they do not exceed 650 µg/m³ in the central and southern parts. At the weekend, lower concentrations dominated the building, while the maximum $PM_{2.5}$ value was found to be 700 µg/m³. Maps are presented in Figure 4 to show $PM_{2.5}$ concentrations at 13:00 on weekends and weekdays.

Looking at the results obtained from the 15.00 hours sampling, the average $PM_{2.5}$ values at the weekend were found to be higher than the weekday values, with a value of 2600 µg/m³, showing that the region with the most pollution corresponds to the J point. The fact that the restaurant has a wide front façade causes all the pollutants and PM2,5 particles formed in the case of using the stoves at the back, to spread directly to that area. Weekday average was found to be 2100 µg/m³. Weekday results were higher at point B, similar to the 13.00-hour average. The mean concentrations at 15.00 hours are shown in Figure 5.



a. **b.**

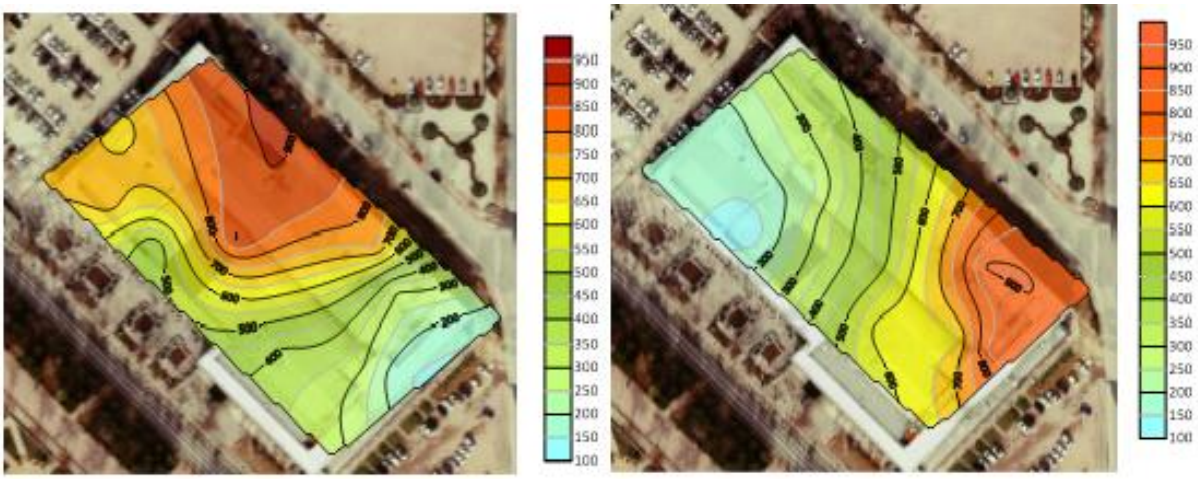
Figure 4. Gokkusagi Shopping Center at 13:00 (**a-**Weekdays, **b**-Weekend average)



a. **b.**

Figure 5. Gokkusagi Shopping Center at 15:00 (a-Weekdays, b-Weekend average)

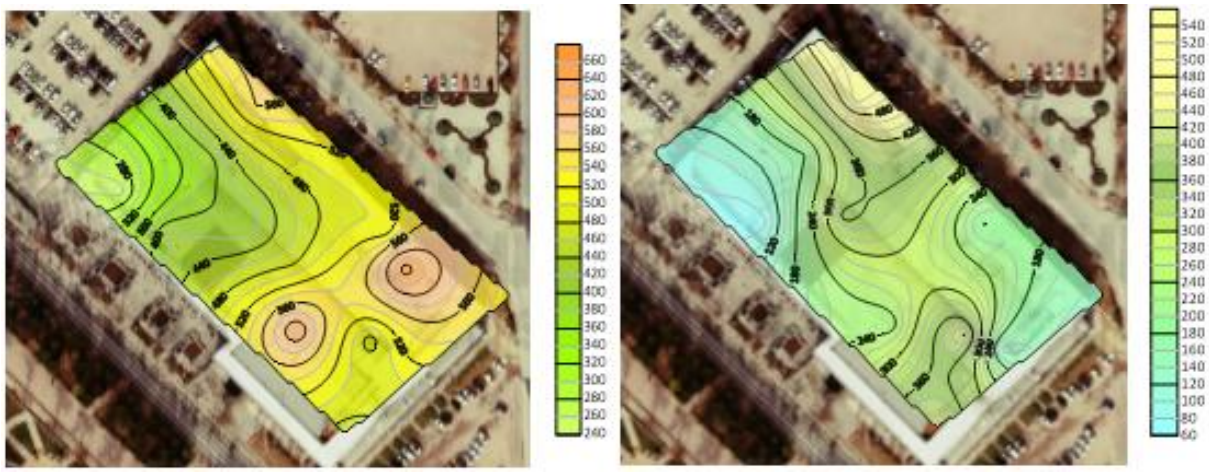
At 17.00, $PM_{2.5}$ values were found to be 950 μg/m^3 on weekdays and weekends with equal concentrations. However, the areas where the pollution is visible are different from each other. While the distribution of pollution during the week is distributed from the north-eastern part of the Rainbow Shopping Centre to other regions, on the weekend map, on the contrary, there is a distribution in the south-eastern part of the building. It is estimated that the pollution originating from the outside environment has penetrated into the indoor environment thanks to the south entrance door located there. The results are shown in Figure 6.



a. **b.**

Figure 6. Gokkusagi Shopping Center at 17:00 (a-Weekdays, b-Weekend average)

Particulate matter $PM_{2.5}$ pollution level further reduced the values at 19.00, when the last measurement of the day was made, and concentrations close to each other were observed throughout the building on weekdays and the average was found to be 660 μg/m³. At the weekend, this value decreased further and the lowest average concentration of the autumn season was found as 540 μg/m³. It is the explanation of why such low $PM_{2.5}$ levels are encountered in Gökkuşağı Shopping Centre at the last measurement hour of the day on the weekend, with staff, students and staff leaving the campus. Weekend and weekday maps of the $PM_{2.5}$ distribution at 19.00 are shown in Figure 7.



a. **b.**

Figure 7. Gokkusagi Shopping Centre at 19:00 (**a**-Weekdays, **b**-Weekend average)

When the measurements made during the study period are examined, the lowest PM2.5 value is 540 μg/m³. This value exceeds the hourly 25 μg/m³ limit set by WHO, EEA and EPA for $PM_{2.5}$ [22, 23]. In Turkey, the standard value for $PM_{2.5}$ in the air quality outdoor assessment management and regulation, which was last updated in 2008, is much higher than 200 μg/m³. The results obtained should be much lower than the HKDYY limit value [24], but exceed these values.

4. Conclusion

In this study, indoor $PM_{2.5}$ air quality, a breathable air pollutant, which is an important environmental problem in Turkey as in the world, has been examined. Although air pollution is a major problem in Konya, one of the most important industrial cities of Turkey, this study for indoor environment is based on shopping malls, the particulate matter $PM_{2.5}$, which carries serious risk factors on human health and is ranked second among air pollutants by the World Health Organization. measurements and modeling were done. In order to make the measurements, it was preferred to make the measurements at the Gökkuşağı Shopping Center located on the Selçuk University Alâeddin Keykubat campus. The sampling period for the measurements was carried out between 24.09.2018 and 07.10.2018. Sampling hours at Gökkuşağı Shopping Center were held between 09:00 and 19:00. How particulate matter PM2.5 affects indoor air quality throughout the period and what causes it are examined. The results were mapped and modeled using the Surfer 16 program. While modeling, the results were interpreted as weekday and weekend averages. As a result, measurement $PM_{2.5}$ values in Gökkuşağı Shopping Center did not exceed WHO's standards.

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 three 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 Gökkuşağı Shopping Center in direct proportion to the patient visiting hours of the hospital.

5. Recommendation

In order for people to spend most of their time in their homes, workplaces, indoor living areas such as public transportation vehicles and shopping malls and to breathe healthy air, these environments and existing ventilation systems, devices and vehicles must be constantly monitored and controlled in terms of quality atmosphere. 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 pollutant source that affects the air quality,
- In order to reduce the pollution concentration, the ventilation systems should be made according to the conditions suitable for the environment in which they will be used, using them correctly and maintaining them at routine 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 modeling 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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