J. Int. Environmental Application & Science, Vol. 17(2): 63-74 (2022)
Research Paper

$PM_{2.5}$ Level in Autumn Period Measurements and Modelling in Novada Mall (Konya, Turkey)

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Received June 056, 2022; Accepted July 20, 2022

Abstract: Air quality takes advantage of a large part of society's wide-ranging offering. For this reason, shows are exhibited on surfaces in competitions. There are possible positive directions in an approach involved in the use in outdoor air. Air quality, uses, substance, gaseous emissions, smoke, water vapor, odour and minerals are used to be preferred for the benefit of the target result for people and other purposes. All over the world, every year in the world 3 million people causes air pollution. The air wheel consists of the use of fuels such as natural gas, coal and gasoline used in industry and vehicles. It is long-lasting with a modern exterior coated and coated. Traffic counties, industrial areas close to city centre, urban uses in life, people and the environment can also cause urban planning. It is one of the crowded city centres of the Konya, and central planning and industrial areas intersection, which cannot be crowded, is also applied in the barbershop. A large part of the society generally prefers to spend their free time by shopping. These areas are also areas to have a good time. Novada Mall is one of crowded places. Employees and visitors in the shopping centres are in contact with the ambient air for a long time. The importance of air pollution in these areas is revealed. To carefully monitor the air quality in these areas, measurements should be made and evaluated, and if necessary, measures should be taken. In the current situation, improvement planning is important for air quality to reach the determined target to achieve the desired results. In this study, $PM_{2.5}$ measurements were made in Novada Mall, and air pollution models were created for all inland areas. The obtained values showed that the air quality of this place is better than other shopping areas compared with Novada land.

Keywords: *Air quality, indoor, measurement, modelling, Particulate matter, $PM_{2.5}$, shopping malls.*

Introduction

$PM_{2.5}$ particulates are fine, inhalable particles with a diameter of 2.5 μ or smaller (Kunt et al, 2020). The fine particulates, which are about 30 times smaller than the width of a human hair, can travel deeply into the lungs and cause both short-term and long-term health effects. These studies shed that exposure of PM has been found different health problems (Goudarzi *et al*., 2013; Malig & Ostro, 2009; Host *et al*., 2008; Qiu *et al*., 2012). 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, or polluted air is important for humanity. Europe's air quality has improved in recent years, due to legislation, advances in technology and the reduction of fossil fuels that cause heavy pollution in many countries. However, many people, especially those living in cities, continue to be adversely affected by air pollution (EPA, 2020; Graff *et al*., 2009; Dursun, 2021; Dursun *et al*., 2021). Given its complexity, tackling air pollution requires action that needs to be coordinated at many levels (Manisalidis *et al*., 2020; Eze et al., 2014; Dursun, & Naseer Qasım, (2021)). The long-term effects associated with air pollution are chronic asthma, pulmonary insufficiency, cardiovascular diseases, and cardiovascular mortality. According to a Swedish cohort study, diabetes seems to be induced after long-term air pollution exposure (USGCRP, 2009). Moreover, air pollution seems to have various malign health effects in early human life, such as respiratory, cardiovascular, mental, and perinatal disorders (USGCRP, 2009), leading to infant mortality or chronic disease in adult age (Kelishadi & Poursafa, (2010; Manucci & Franchini, 2017).

The main sources: Combustion sources in indoor settings, including tobacco, wood and coal heating and cooking application, and fireplaces can release harmful combustion by-products such as carbon monoxide and particulate matter directly into the indoor environment. Cleaning supplies, paints, insecticides, and other commonly used products introduce many different chemicals, including volatile

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organic compounds, directly into the indoor air. Building materials are also potential sources, whether through degrading materials e.g., asbestos fibbers released from building insulation) or from new materials (*e.g.,* chemical off-gassing from pressed wood products (Kaya & Öztürk, 2012; EPA, 2022). Other substances in indoor air are natural origin, such as radon, mould, and pet dander.

Materials and Methods

Study Area

The study area consists of a shopping centre, with a total area of 33000 m². It has 2 outdoor and one indoor parking lots, 51 stores, 12 restaurants and 3 playgrounds. 3 of the 4 entrance doors are located on the front of the building facing the main street. For this reason, it is directly exposed to air pollution caused by traffic. This 4-storey building looks like the letter L when viewed from the satellite image, as shown in Figure 1.

The other entrance door is used as a parking garage entrance on the -1 floor and there is no direct exposure to outdoor air pollution. There are cash machines, travel agency and tailor shops on this floor. The first measurement point was chosen right in front of the entrance door. Figure 1.

The ground floor (0 level) has two entrance doors at the same level on the north and south facades. On this floor, there are mostly household goods, electronic goods stores, cosmetics, a small number of coffee shops and clothing stores. The possible source of pollution was mostly thought of as the exhaust fumes carried in from the open parking lot located at the front of the shopping mall and where both doors open directly there.

Figure 1. Measurement points according to floors in Novada Mall, (adapted from URL-1)

The 1st floor consists entirely of clothing stores, and the possible source of pollutants is considered as fabric types and store perfumes. The fourth entrance door is located at the back of this floor. There is a ventilation system on the ceiling and the floor in the entire building is covered with ceramic porcelain.

The 3rd floor consists of restaurants, fast food kitchens and children's playgrounds. The most significant source of pollutants of this floor is emissions from cooking in restaurants. Restaurants are defined as publicly communal indoor environments where many people spend most of their time. For this reason, the clean and healthy air in these areas not only protects the visual appearance, but also protects the health of employees and visiting customers (Lee *et al*., 2001). Small-sized particulate matter (organic and inorganic) and carbon monoxide in kitchens are the main source of combustion in cooking activities (Morawska & Zhang, 2002).

When we look at the playgrounds, the floor coverings that can affect the air quality and cause the spread of volatile organic compounds, the play building materials used, the respiratory rate and mobility during the activities can be listed as the inadequacy of the ventilation system in that area. Novada outlet shopping and living centre located near the bus station area, which is known as the new development area of the city, was opened for use in 2015.

This mall has fresh air handling unit on the entrance, 1st and 2nd floor. The air conditioning system at the entrance and the first floor gives the indoor air to the floors, after taking the air from the outside in normal air temperatures and returns it to the inside by passing it through the filter inside itself (Figure

2). On the second floor, the ventilation system works in a different way and sends the air taken from the outside directly to the outside after giving it in once. The reason why it works in this way is that the pollution rate on the said floor is released in high concentrations from the dining and playground areas.

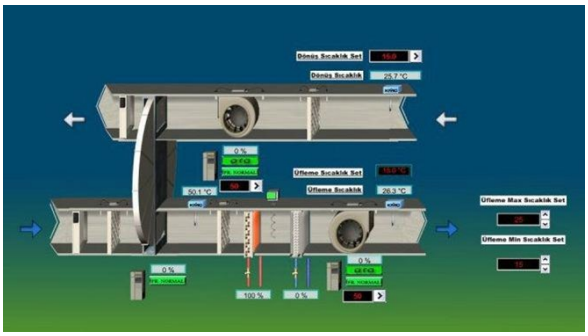

Figure 2. Novada shopping centre ventilation system

Rapid population growth is produced environmental problems, transforming natural environments into agricultural lands, People spend 87% of their time indoors and these environments have poor air quality, indoor data should be examined instead of outdoor data 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 NOVADA Mall at Selçuklu Region (Konya), and three-dimensional pollution maps were obtained by modelling the indoor distribution.

Results and Discussion

Novada Mall the opening and closing hours of the shopping center between the hours of weekdays and weekends (09.00 - 23.00). The first measurement of the day started at 11:00, with every two-hour between each measurement, a total of 6 measurements were made, and the last measurement was made at 21:00. According to the measurement points made, a separate map was drawn for each floor. As a result of the study, the average values of $PM_{2.5}$ obtained from the examination of all data on weekdays and weekends are 345.98 µg/m3 and 652.57 µg/m^3 for summer. Figure 3 shows the results obtained from the measurements made during the autumn season, at 11:00 on weekdays, were found as follows, respectively, according to the layers: (-1) layer 840 µg/m3, (zero) the ground layer 520 µg/m^3, the first layer 290 µg/m3 and the second layer 240 µg/ m^3.

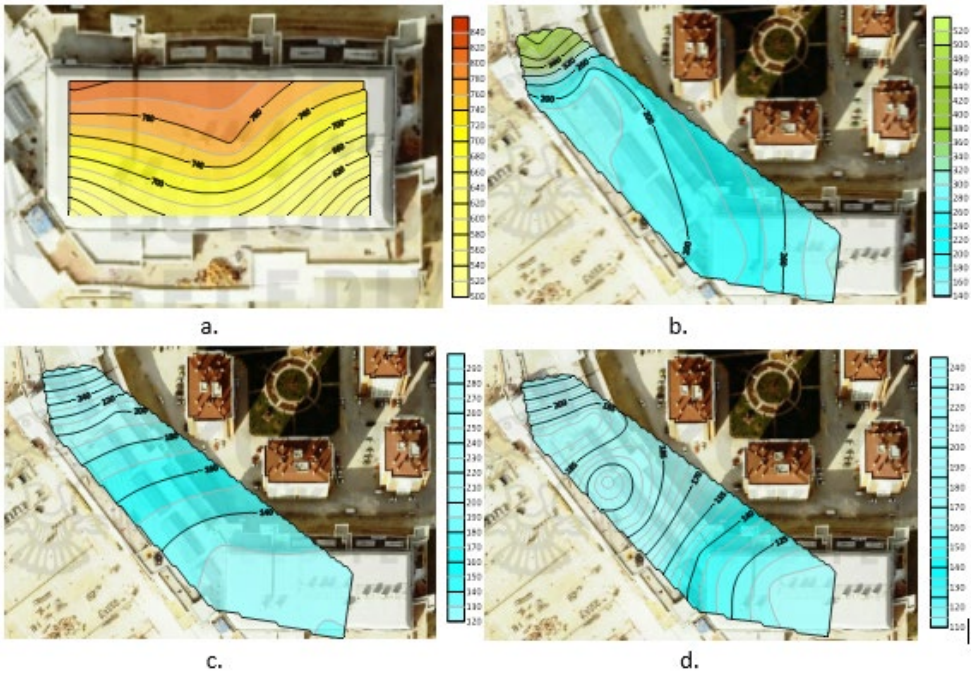

Figure 3. In Novada Mall, autumn season is at 11:00 am the weekdays. **a.** (-1) floor, **b**. (0) ground floor, **c**. (1) 1st floor, **d**. (2) 2nd floor average

The results obtained from the measurements made in the autumn season, at 11:00 on the weekend, $PM_{2.5}$ concentrations were found as follows, respectively, according to the layers: (-1) layer 700 µg/m^3, (zero) the ground layer 560 µg/m^3, the first layer 950 µg/m^3 and the second layer 950 µg/ m^3. The level of pollution seen on the first and second floors in the upper part of the building was due to the playgrounds located there. The maps are shown in Figure 4.

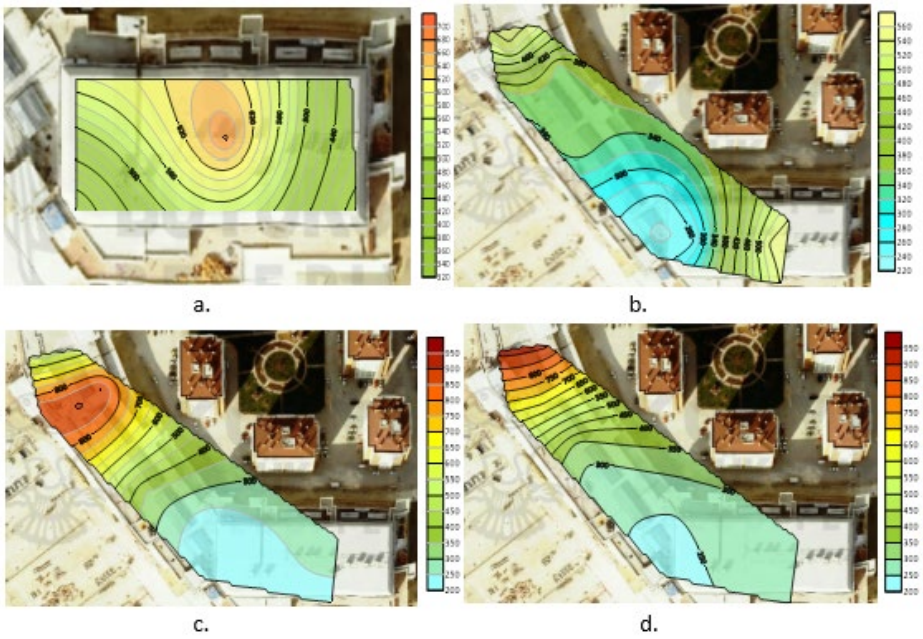

Figure 4. In Novada Mall, summer season is 11.00 a.m. on the weekends average (µg/m^3). **a.** (-1) floor, b. (0) ground floor, c. (1) 1st floor, d. (2) 2nd floor average

The weekday results of the measurements made at 13.00 were as follows: 1700 µg/m^3 for the minus first layer, (zero) ground layer 400 µg/m3, the first layer 205 µg/m^3 and the second layer 560 µg/m3. The highest value was seen on the minus first floor. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 5.

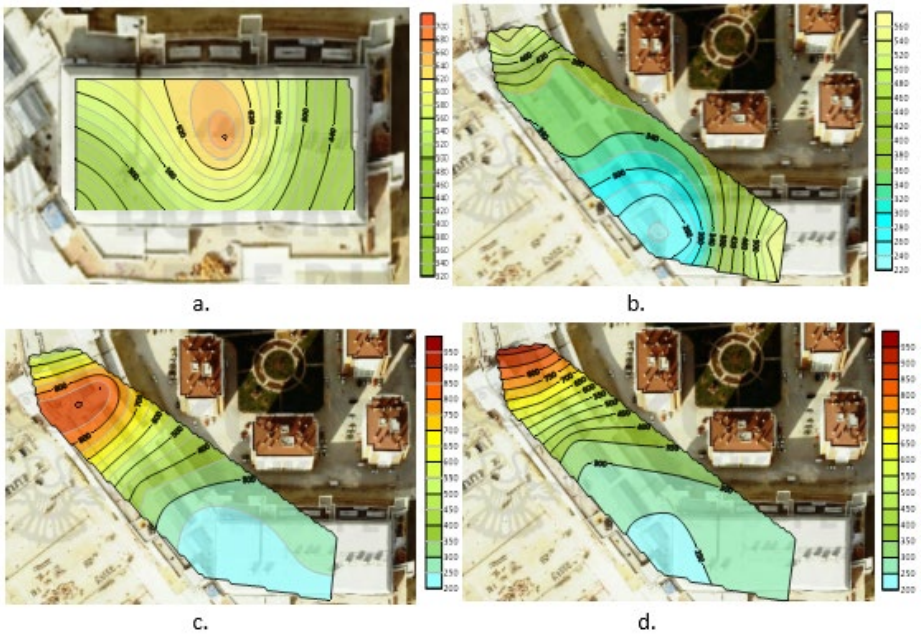

Figure 5. In Novada Mall, summer season is 13.00 a.m. on the weekday average (µg/m^3). **a.** (-1) floor, b. (0) ground floor, c. (1) 1st floor, d. (2) 2nd floor average

The weekend results of the measurements made at 13.00 were found as follows: minus the first layer 760 µg/m^3, (zero) ground floor 880 µg/m^3, first layer 440µg/m^3 and second layer 740 µg/m^3. The point of pollution seen on the ground floor exactly corresponds to where the entrance gate A of the shopping mall is, so the high level of pollution seen there means that there is a pollutant spreading from the outside environment to the indoor environment. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 6.

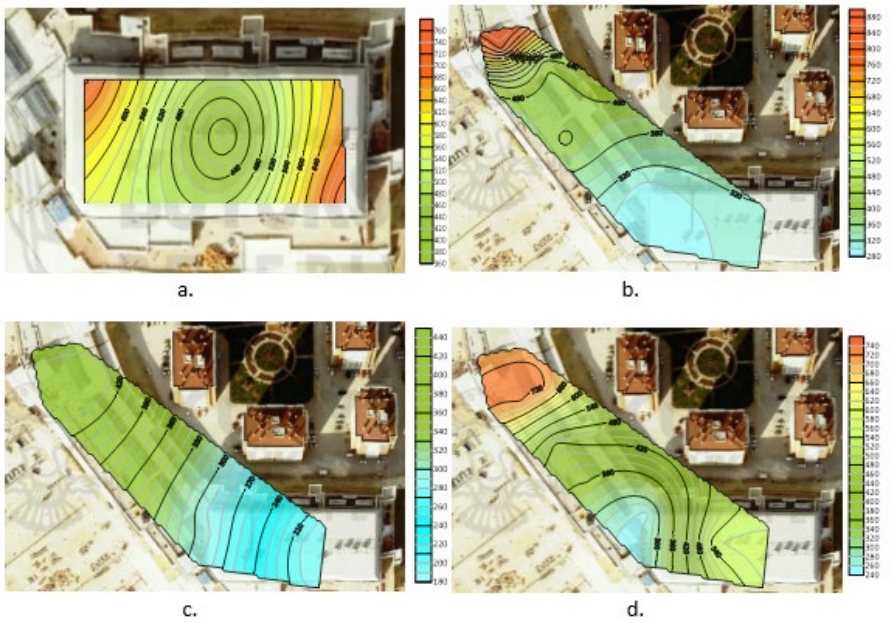

Figure 6. Autumn season at Novada Mall at 13.00 a.m. on the weekends average (µg/m^3). **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 15:00 were found as follows: minus the first layer 940 µg/m^3, (zero) ground layer 520 µg/m^3, first layer 320µg/m^3 and the second layer 330 µg/m^3. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 7.

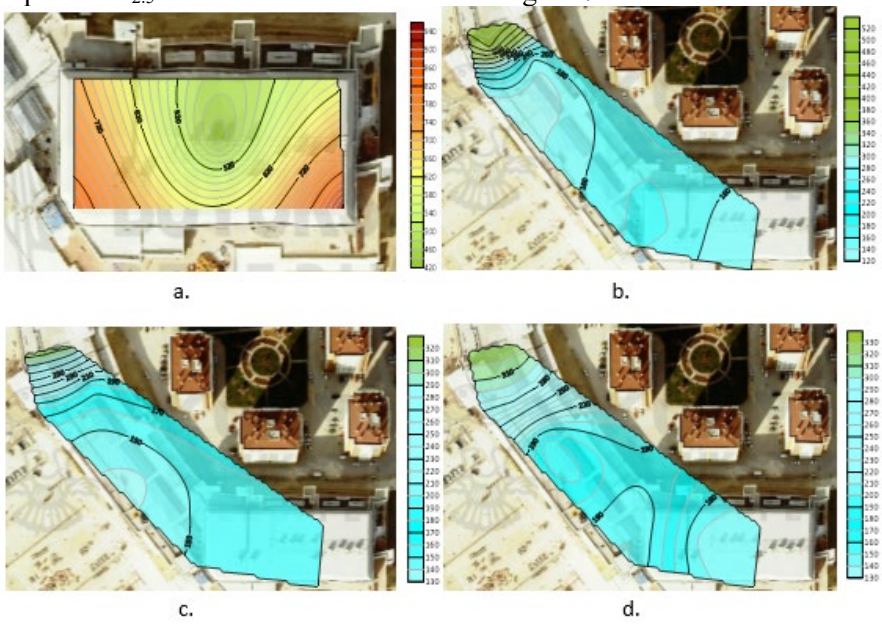

Figure 7. In Novada Mall, autumn season is at 15.00 a.m. on The weekday average (µg/m^3). **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 15.00 pm were found as follows: minus the first layer was 2300 µg/m^3, (zero) the ground layer was 1100 µg/m^3, the first layer was 840 µg/m3 and the second layer was 1800 µg/m^3. The highest concentrations of the autumn season were seen here. Due to

the weekend, the number of visitors to the mall increases after noon. Therefore, the concentration of $PM_{2,5}$ caused by the crowd was found to be high in all floors. Intense pollution, especially in the playground and exhibition areas, was clearly observed on the maps. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 8.

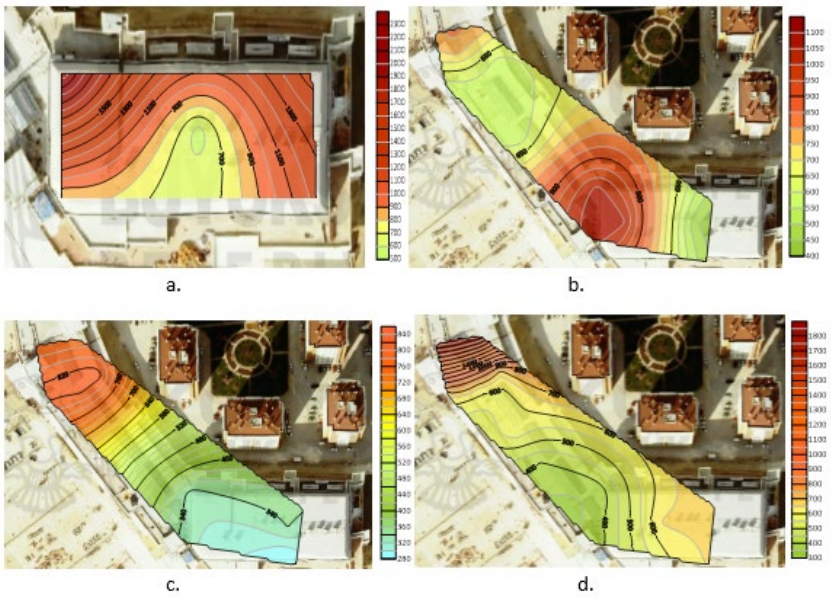

Figure 8. Autumn season at Novada Mall at 15.00 a.m. on the weekends average (µg/m^3). **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 17.00 were found as follows: 1900 µg/m^3 for the minus first floor, 335 µg/m^3 for the (zero) ground layer, 380 µg/m^3 for the first layer and 410 µg/m^3 for the second layer. The highest concentration of $PM_{2.5}$ was observed on the minus first floor. Since it coincides with the evening hours and there is no ventilation on the mentioned floor, it is a possible result that the level of particulate matter increases as the crowd increases in the shopping mall. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 9.

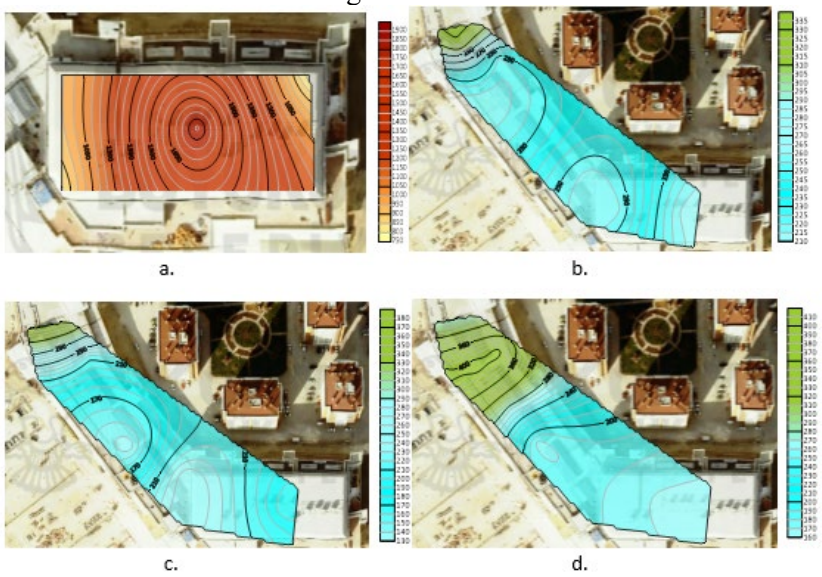

Figure 9. Autumn season at Novada Mall on the weekday average (µg/m^3) at 17.00 a. **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 17.00 were as follows: minus first floor 740 µg/m3, (zero) ground floor 780 µg/m3, first floor 780 µg/m3 and second floor 1450 µg/m3. The highest concentration was observed on the second floor. As the evening hours approached, the increasing

number of visitors caused a great density on the dining floor. Therefore, as the number of working stoves and toys increased, there was an increase in the PM2.5 level. Concentrations in other layers were found to be very close to each other. Distribution maps of PM2.5 concentrations are shown in Figure 10.

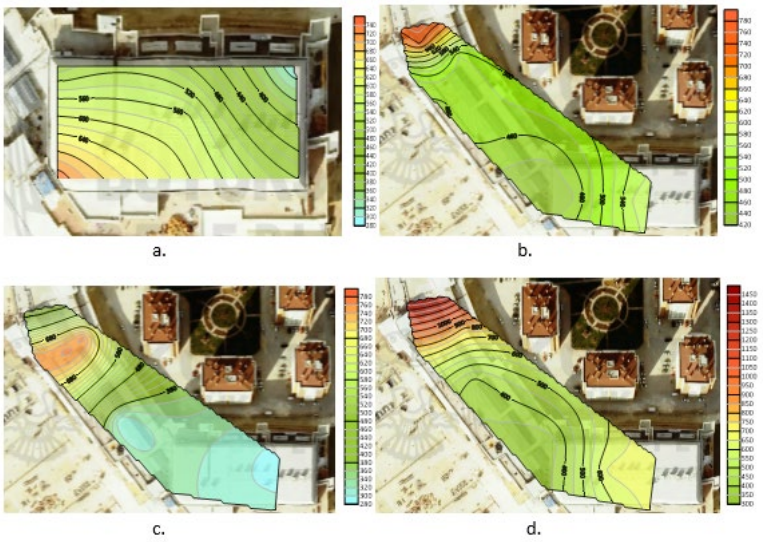

Figure 10. At Novada Mall, autumn season is at 17.00 on the The weekend average (µg/m^3). **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 19.00 were found as follows: minus first floor was 1350 µg/m3, (zero) the ground floor was 430 µg/m3, the first layer was 370 µg/m3 and the second layer was 410 µg/m3. Concentrations are like those seen at 17:00. Distribution maps of PM2.5 concentrations are shown in Figure 11.

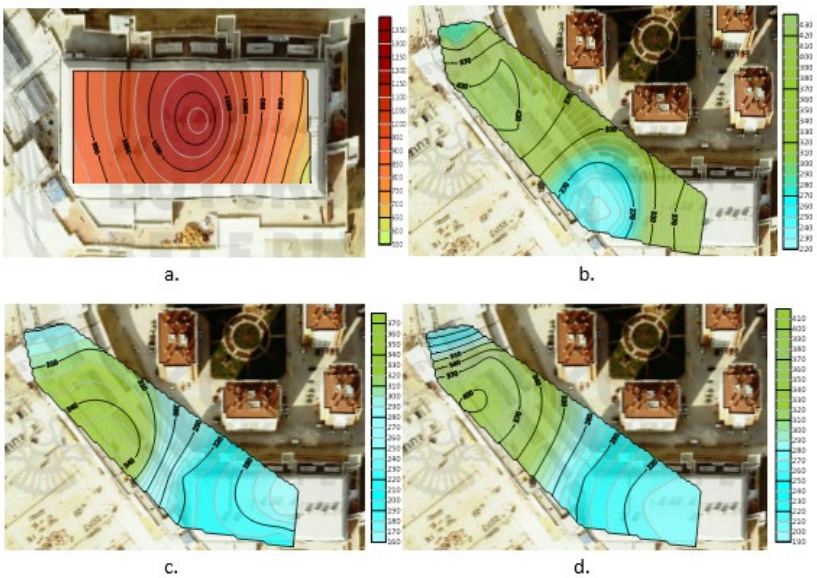

Figure 11. In Novada Mall, autumn season is at 19.00 a.m. on the average weekday (µg/m^3). **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 7 pm were found as follows: minus first floor 880 µg/m3, (zero) ground floor 790 µg/m3, the first floor 840 µg/m3 and the second floor 1350 µg/m3. Although the concentrations were similar at 17.00, the pollution distribution differed. It has been observed that $PM_{2.5}$ is distributed throughout the building on all floors. It is estimated that as the number

of visitors increases in the evening hours, the fresh air spreading performance of the ventilation decreases. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 12.

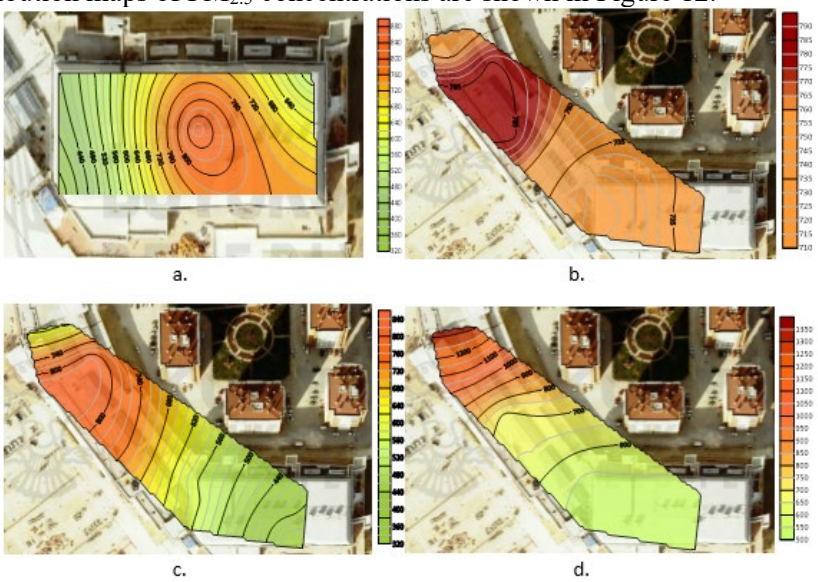

Figure 12. At Novada Mall at 19.00 a.m. on the the weekend average (µg/m^3) of the autumn season. **a.** (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 21:00 were found as follows: minus first layer was 670 µg/m^3, (zero) the ground layer was 840 µg/m^3, the first layer was 820 µg/m^3 and the second layer was 820 µg/m^3. Compared to the previous measurement time, $PM_{2.5}$ values decreased on the minus first floor at 21.00 and increased on the other floors. Pollution was also observed in the same parts. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 13.

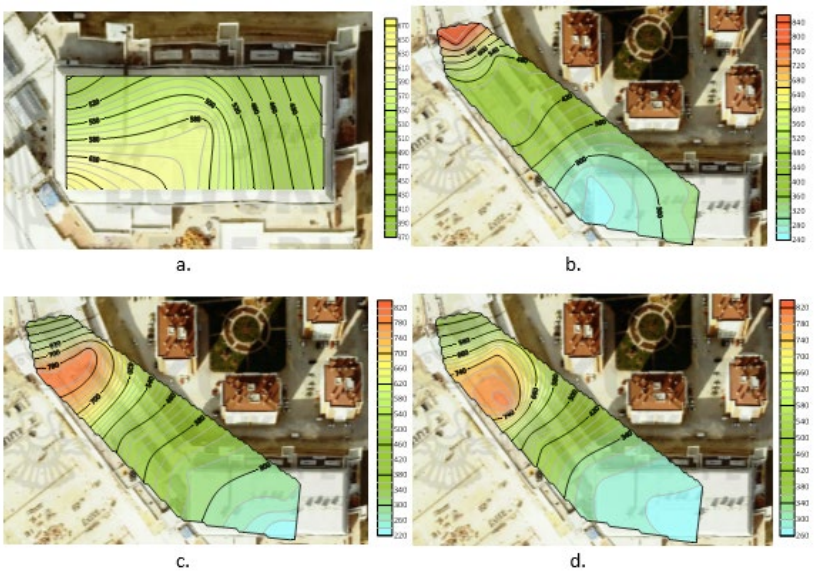

Figure 13. In Novada Mall, autumn season is at 21.00 a.m. on the weekday average (µg/m^3). **a.** (-1) floor, **b**. (0) floor, **c.** (1) floor, **d.** (2) floor average

The weekend results of the measurements made at 21:00 were found as follows: minus first floor was 590 µg/m3, (zero) the ground floor was 1400 µg/m3, the first floor was 1250 µg/m3 and the second layer was 1400 µg/m^3. As a result of the closure of the shops on the minus first floor at the last measurement hour of the day, $PM_{2.5}$ values decreased slightly, while an increase was observed on the other floors. Visits to the mall at the weekend are more intense than during the week, which means that this allows for high pollution levels. Pollution is concentrated towards the upper corner of the building on all three floors, and it is estimated that the ventilation system is insufficient at certain points due to

the crowd. In addition, there are playgrounds in those areas on the 1st and 2nd floors, which means that these areas are occupied and actively used at the most crowded hour of the day. Distribution maps of $PM_{2.5}$ concentrations are shown in Figure 14.

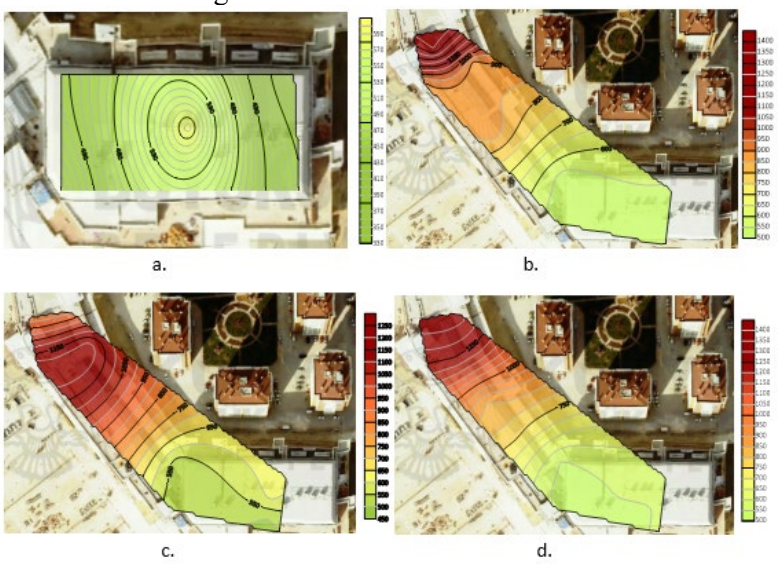

Figure 14. Autumn season at Novada Mall at 21.00 a.m. on the weekends average (µg/m^3). **a.** (-1) floor, **b**. (0) floor, **c.** (1) floor, **d.** (2) floor average

In summary, the findings obtained in the autumn season are as follows: the average values of the weekend were found to be higher than the weekdays, higher values were obtained in general compared to the summer season, the highest $PM_{2.5}$ concentration of the period was found to be 2300 µg/m3 on the first floor. While the other floors showed similar results in all measurement hours, they gave the highest values at 21.00 on the weekend.

All values exceed the hourly 25 µg/m^3 limit set by WHO, EEA and EPA for $PM_{2.5}$. The standard value for $PM_{2.5}$ in the air quality assessment management and regulation, which was last updated in 2008 in Turkey, is 200 µg/m3. The results obtained exceed the Turkish APCR limit value.

Conclusions

In this study, which was started in Konya, one of the most important industrial cities of the country, based on shopping centers, particulate matter $PM_{2.5}$ 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 (WHO, 2020; Dursun & Ayturan, 2022). The environment of Novada outlet mall were deemed suitable and selected for the measurements. In summary, the findings obtained in the autumn season are as follows: the average values of the weekend were found to be higher than the weekdays, higher values were obtained in general compared to the summer season, the highest $PM_{2.5}$ concentration of the period was found to be 2300 µg/m3 on the first floor. While the other floors showed similar results in all measurement hours, they gave the highest values at 21.00 on the weekend.

All values exceed the hourly 25 µg/m^3 limit set by WHO, EEA and EPA for $PM_{2.5}$. The standard value for $PM_{2.5}$ in the air quality assessment management and regulation, which was last updated in 2008 in Turkey, is 200 µg/m^3. The results obtained exceed the AQCA limit value.

Measurements were made on the minus first, entrance, first and second floors of the shopping mall. The highest concentrations were seen in this mall minus the first floor. Opening the only door on this floor where there is no ventilation to the parking garage caused the emissions from the vehicles to spread indoors.

The relatively low concentrations found in Novada Mall are due to the presence of a clean air plant operating here. These power plants, operating on the entrance, first and second floors, changed the indoor air of the building and helped to breathe quality air. In addition, cleaning activities continue throughout the day. High concentrations are mostly in the food layer; It has been found in areas where restaurants and playgrounds are located. This building, which was put into use in 2015, has less pollution reflected in the environment due to the building material and the age of the building.

Recommendations

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 as atmospheric air quality. 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, due to the lack of standards determining indoor air quality in Turkey until today, it is recommended that the relevant institutions act as soon as possible to establish standard values for indoor 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. When the measurements made during the study period are examined, the lowest $PM_{2.5}$ value is about 300 μg/m^3. This value exceeds the hourly 25 μg/m^3 limit set by WHO, EEA and EPA for $PM_{2.5}$ (URL-5; URL-6). 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/m^3. The measurable results obtained should be much lower than the APCA limit value (ÇOB, 2008), but exceed these values.

Acknowledgement: This paper has been prepared a part of Mina Naseer Qasim's MSc.Thesis and presented IMASCON2022, Kocaeli, Türkiye.
Funding: This research has been funded by Selcuk University, Scientific Research Found, Project no:18201117.
Author contributions: Sukru Dursun: Conceptualization, Methodology, -Reviewing and Editing; **Mina Naseer Qasim:** Investigation, Data curation, Writing-Original draft preparation, Modelling.
Conflicts of interest: The authors declare no conflicts of interest.

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