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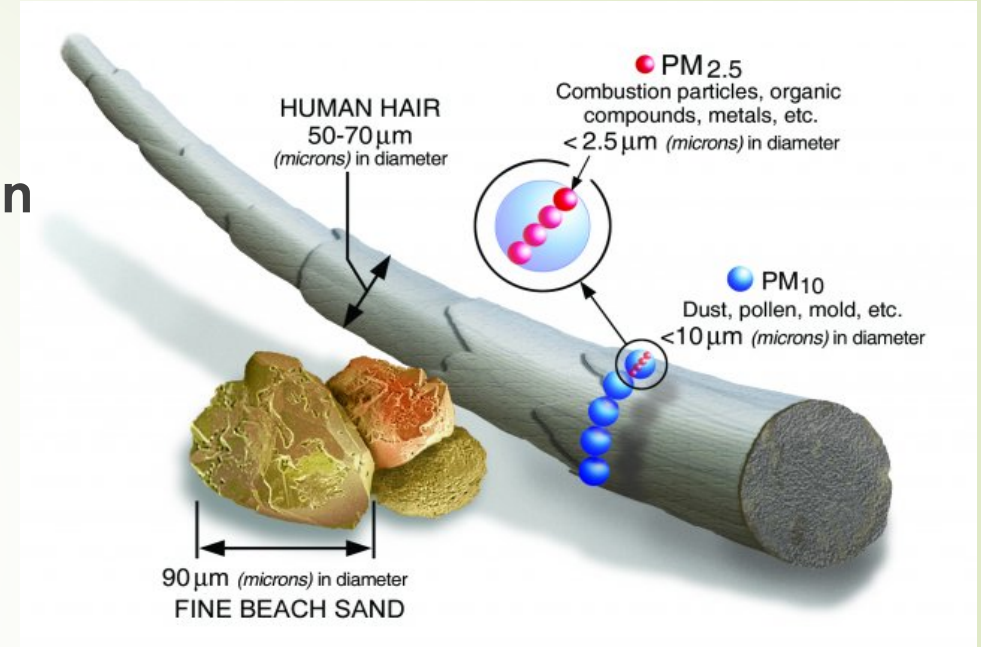
Modelling Results Obtained from $PM_{2.5}$ Measurements from Gökkuşağı Shopping Center (Konya, Turkey) in Winter Period

Abstract

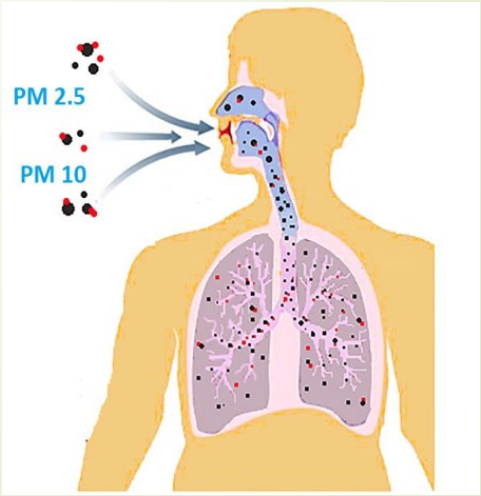
- The environment where people live, work, rest, briefly spend 90% of a day's time, are also closed or half-closed spaces. The air of these places we are in is polluted by gas, dust, and organic vapor emissions that we create because of our own activities. So much so that sometimes the indoor air quality can be so polluted that it cannot be compared with the outdoor air quality. Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health. These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Source attribution/apportionment to quantify the contributions of different sources, sectors, and regions to ambient $PM_{2.5}$ concentrations is not done in this study. Further research is required to determine the proportion of health impacts (from outdoor $PM_{2.5}$ exposures) attribute-able to particle emissions from household solid fuel combustion. Aside from outdoor health impacts, severe health risks from exposure to in-door particle emissions are a matter of concern and must therefore be estimated. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream. Exposure to such particles can affect both your lungs and your heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems. In the world, air pollution is one of the largest mortality risk effects for life. The World Health Organization's recommended guidelines for healthy air is exceeded over of the world population. Health studies show for $PM_{2.5}$ exposures contribute significantly affected. Nearly, most of the population lives indoor areas where $PM_{2.5}$ concentrations surpass the WHO guideline value (5 $\mu g/m^3$) recognizing air pollution as the leading health risk factor in the shopping centres. The values obtained in the measurements made in the winter season showed that; $PM_{2.5}$ values in Gökkuşağı Shopping Center were above the limit values and were even higher in areas with insufficient ventilation and cooking units.

Introduction

- $PM_{2.5}$ particulates are fine, inhalable particles with a diameter of 2.5 μ or smaller.
- These 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.



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.



$PM_{2.5}$ is also produced by common indoor activities. Some indoor sources of fine particles are:

Normal activities of people, cleaning activities, moving, skin rashes, dust particles precipitated from fabric and paper fibbers may cause the dispersal of dust particles to the environment.

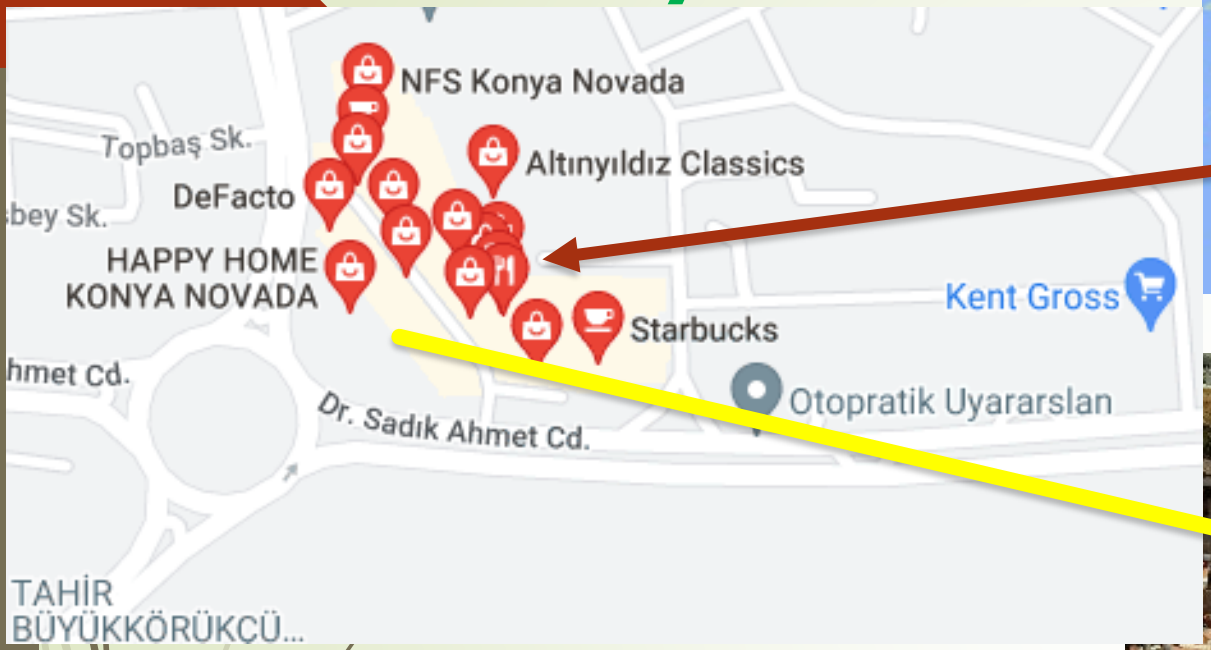
The main sources

- 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 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). Other substances in indoor air are of natural origin, such as radon, mould and pet dander.

Significantly affects on indoor air quality

- Some health effects may show up shortly after a single exposure or repeated exposures to a pollutant. These include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable. Sometimes the treatment is simply eliminating the person's exposure to the source of the pollution, if it can be identified. Soon after exposure to some indoor air pollutants, symptoms of some diseases such as asthma may show up, be aggravated or worsened.
- The likelihood of immediate reactions to indoor air pollutants depends on several factors including age and pre-existing medical conditions. In some cases, whether a person reacts to a pollutant depends on individual sensitivity, which varies depend from person to person. Some people can become sensitized to biological or chemical pollutants after repeated or high level exposures.

Study Area



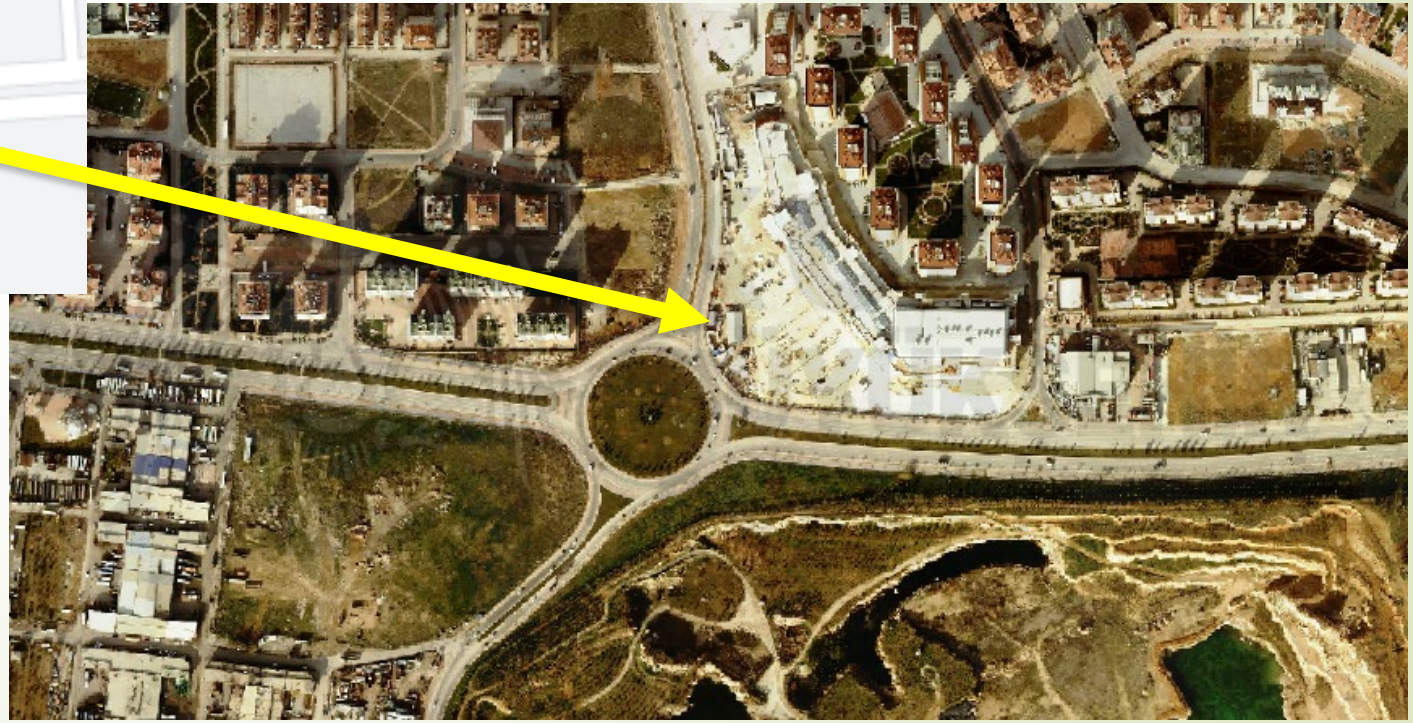


Figure 1. Measurement points according to floors in Novada AVM, (adepted from URL7)

Study Area

- For this reason, it is directly exposed to air pollution caused by traffic. 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 cafes 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.

Study Area

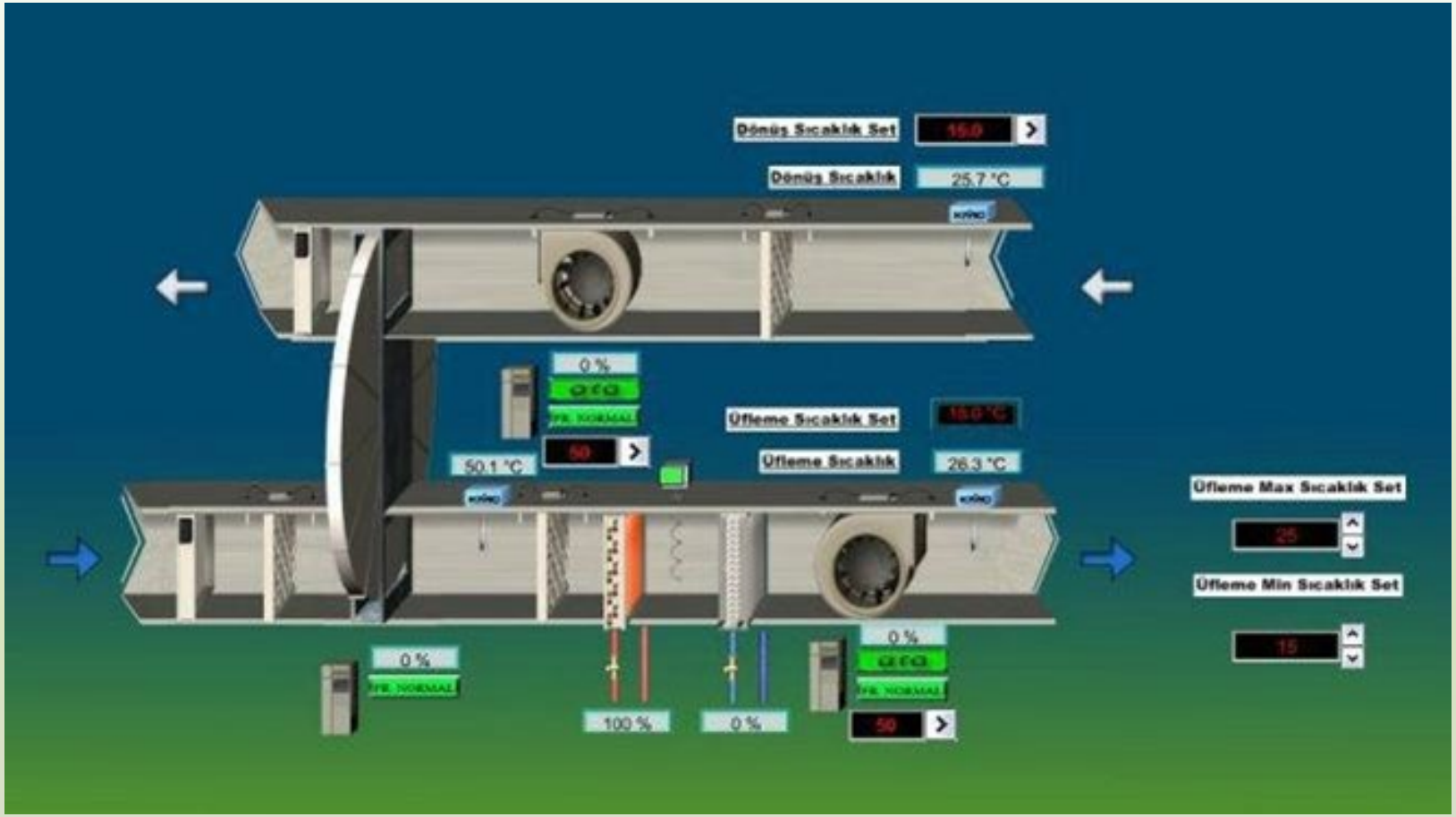
The 1st floor consists entirely of clothing stores, and the possible source of pollutants is considered as fabric types and store perfumes. The fourth entrance door is located at the back of this floor. There is a ventilation system on the ceiling and the floor in the entire building is covered with 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. Small-sized particulate matter (organic and inorganic) and carbon monoxide in kitchens are the main source of combustion in cooking activities.

Study Area

- 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.
- 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).

Study Area



- 3.3. Novada shopping centre ventilation system

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.

Particle Counter PCE-PCO1

Golden Software-16 Surfer is a program capable of modeling and creating a 3D graphical setup system that includes basic statistics. It is used to create contour maps and obtain 3D images by processing complex data obtained from various processes and creating networks.

Modelling programme SURFER

Figure 2.

Particulate Matter $PM_{2.5}$ measurement method

In this study, **summertime** was chosen, **two-day** measurement intervals were determined on **weekdays** and **weekends**. The periodical measurement period was completed as 4 days.

The daily measurement program 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 ,Y and Z coordinates represented the measured PM2.5 values.

Statistical calculations were made by converting the prepared data into tables.

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.

Study 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 shopping centre, with a total area of 33,000 m², has 2 outdoor and one indoor parking lots, 51 stores, 12 restaurants and 3 playgrounds.
- Consisting of 4 floors, this building looks like the letter L when viewed from the satellite image, and 3 of the 4 entrance doors are located on the front of the building facing the main street. Figure 1.

Objectives

- 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 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 NOVADA Shopping Center at Selçuklu Region (Konya), and three-dimensional pollution maps were obtained by modeling the indoor distribution.

Giriş

The first measurement of the day started at 11:00, and 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 336.97 µg/m3 and 322.55 µg/m^3 for winter, Figure 4

Results and Discussion

Novada shopping center the opening and closing hours of the shopping center between the hours of weekdays and weekends (11.00 - 19.00)

The weekday average (µg/m^3)

The results obtained from the measurements made during the winter season at 1 were found as follows, respe floors: minus the first floor 8 floor 730 µg/m3, the first flo second floor 630 µg/ m3. Th seen on the minus first floor floor from the same point. T was observed at the 11th me first floor. It is considered as pollution at this point where playground are located. A po exhibitions and playgrounds on the second floor is reflected on the map. Distribution maps of PM2.5 concentrations are shown in Figure

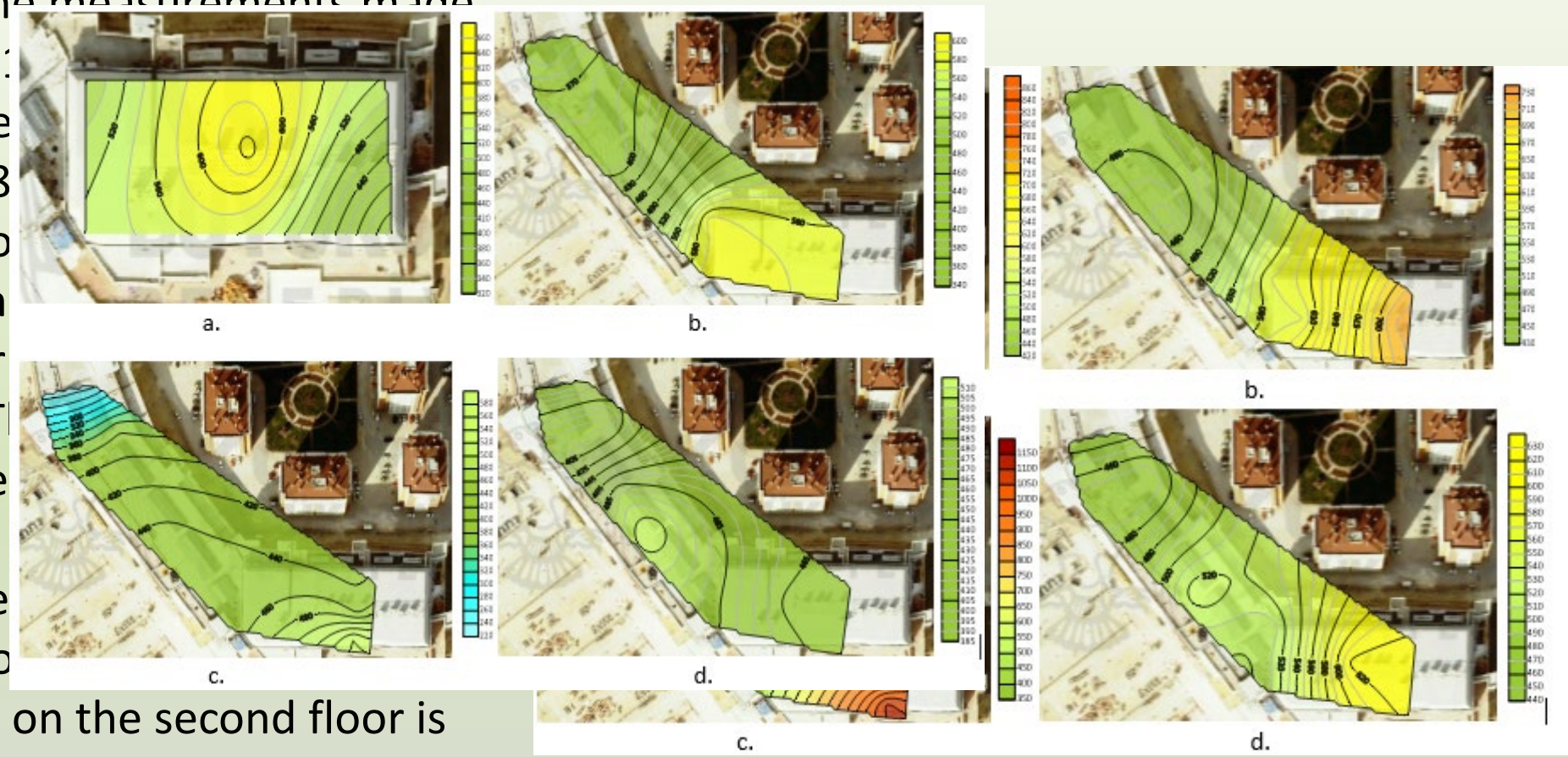


Figure 4. In Novada AVM, winter season is at 11:00 am the weekdays. **(-1) floor, b. (0) ground floor, c. (1) 1st floor, d. (2) 2nd floor average**

Results and Discussion

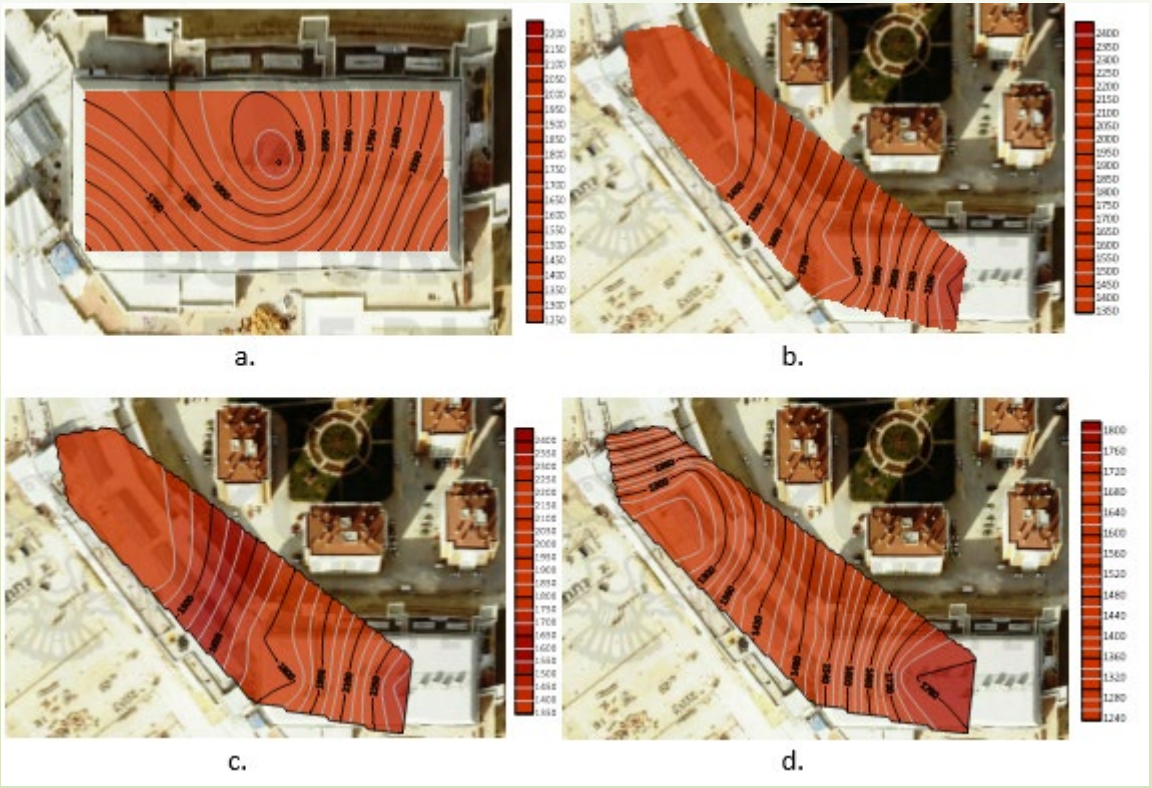


Figure 5. In Novada AVM, winter is 11.00 a.m. on The weekends average (µg/m^3). (-1) floor, b. (0) ground floor, c. (1) 1st floor, d. (2) 2nd floor average

PM2.5 concentrations increased sharply at 11:00 am on the weekend. Concentrations were found for each coat: minus 2200µg/m3 for first coat, (zero) ground coat 2400 µg/m3, first coat 1590 µg/m3 and second coat 18800 µg/m3. These values were found to be the highest values of the winter season. Concentrations exceeding 1000 µg/m3 in all floors were observed at levels that would pose serious hazards in all floors. The number of visitors was found to be much higher than during the week, since it was also the weekend at the measurement time that coincided with the moment when the ventilation was not working. Therefore, the highest PM2.5 values were found on the ground floor. Distribution maps of PM2.5 concentrations are shown in in Figure 5.

Results and Discussion

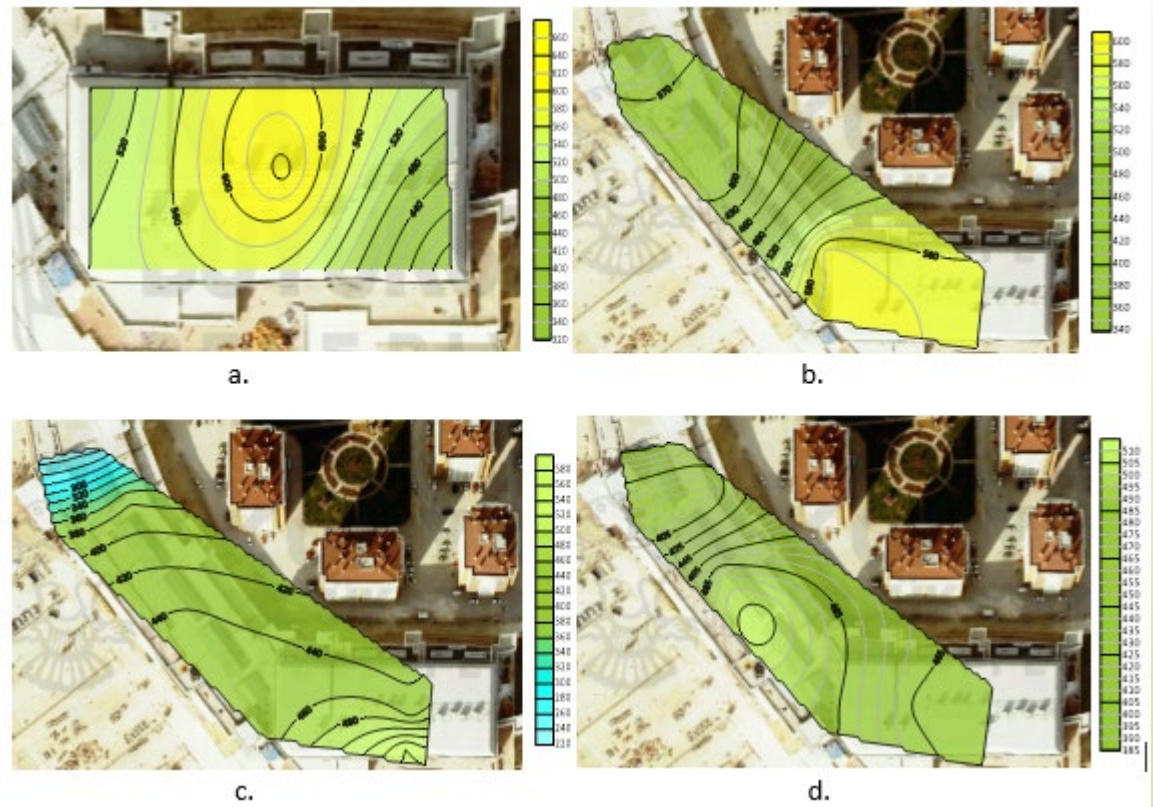


Figure 6. In Novada AVM, winter season is 13.00 a.m. on The weekday average (µg/m^3) . (-1) floor, b. (0) ground floor, c. (1) 1st floor, d. (2) 2nd floor average

The weekday results of the measurements made at 13.00 were as follows: minus the first layer was 660 µg/m3, (zero) the ground layer was 600 µg/m3, the first layer was 580 µg/m3 and the second layer was 510 µg/m3. Values in all floors did not exceed 660 µg/m3. The values were lower than 11:00 am. Distribution maps of PM2.5 concentrations are shown in Figure 6.

Results and Discussion

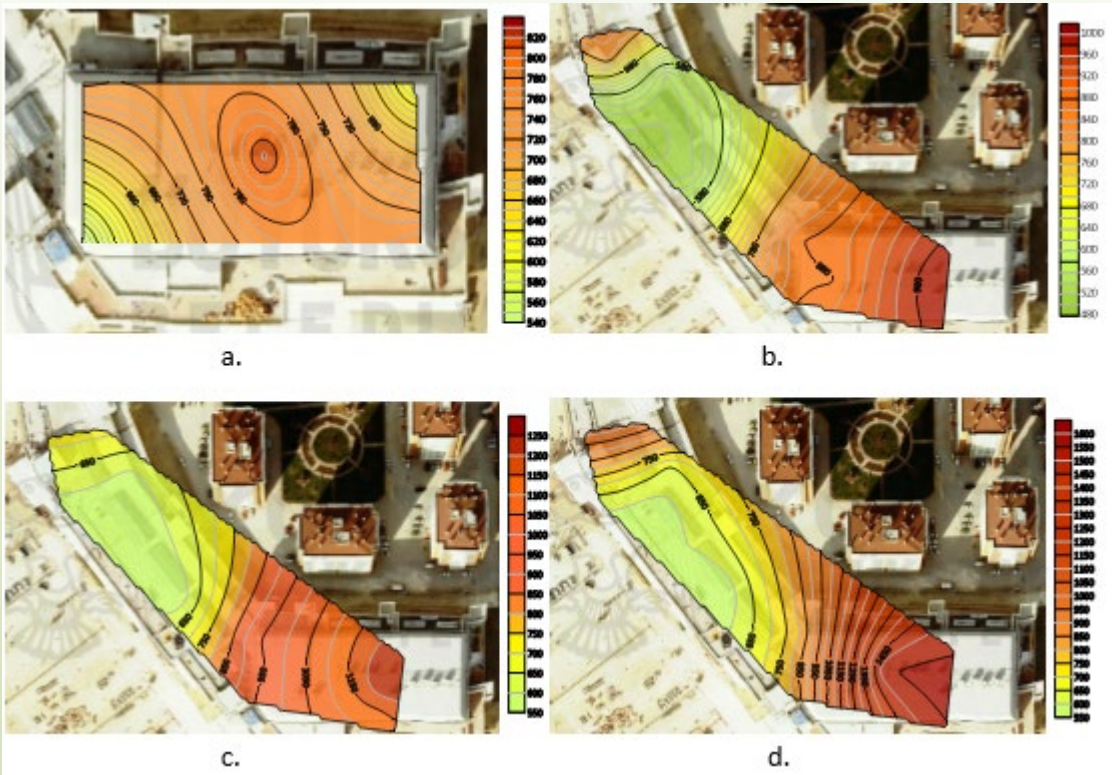


Figure 7. Winter season at Novaland AVM at 13.00 a.m. on The weekends average (µg/m³). (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 13.00 were found as follows: minus the first layer 760 µg/m³, (zero) ground floor 880 µg/m³, first layer 440µg/m³ and second layer 740 µg/m³. 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 7.

Results and Discussion

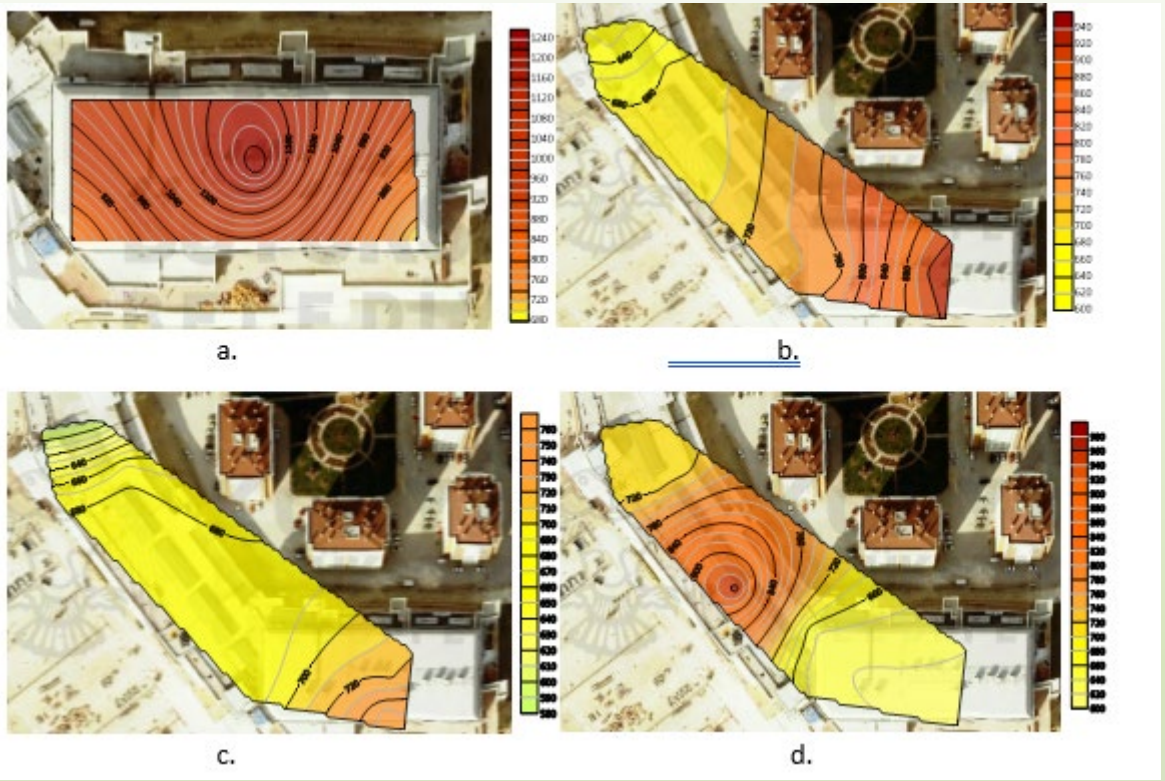


Figure 8. In Novaland AVM, winter season is at 15.00 a.m. on The weekday average (µg/m^3) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 15:00 were found as follows: minus the first floor 1240 µg/m3, (zero) ground floor 940 µg/m3, first floor 760 µg/m3 and second layer 980 µg/m3. After the measurements at 13.00, the values increased again. The values posing a serious level of danger on the minus first floor dispersed from the point where it was connected to the ground floor, causing high concentrations to be observed in the lower part of the building as seen on the map. On the second floor, where there are more preferred and crowded restaurants, PM2.5 level was found to be high. Distribution maps of PM2.5 concentrations are shown in Figure 8.

Results and Discussion

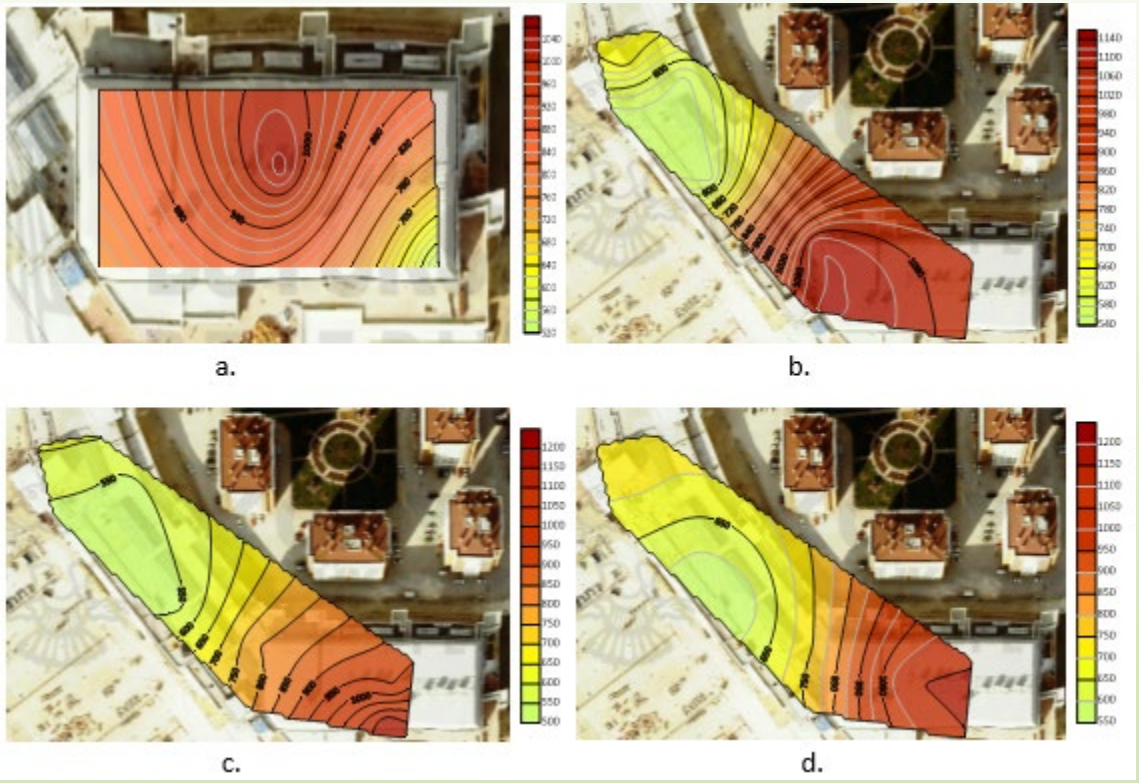


Figure 9. Winter season at Novaland AVM at 15.00 a.m. on The weekends average (µg/m^3). (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 3:00 pm were found as follows: minus the first floor was 1040 µg/m3, (zero) the ground floor was 1140 µg/m3, the first floor was 1200 µg/m3 and the second layer was 1200 µg/m3. It is seen on the maps that PM2,5 concentrations have increased in the lower right part of the building. This area, which corresponds to the third point, is used as an exhibition area at the weekend. The crowd created by the visitors affected the air quality negatively and caused the PM2.5 values to spread to the first and second floors in the same area. Therefore, the modeling result is similar in all three layers. Distribution maps of PM2.5 concentrations are shown in Figure 9.

Results and Discussion

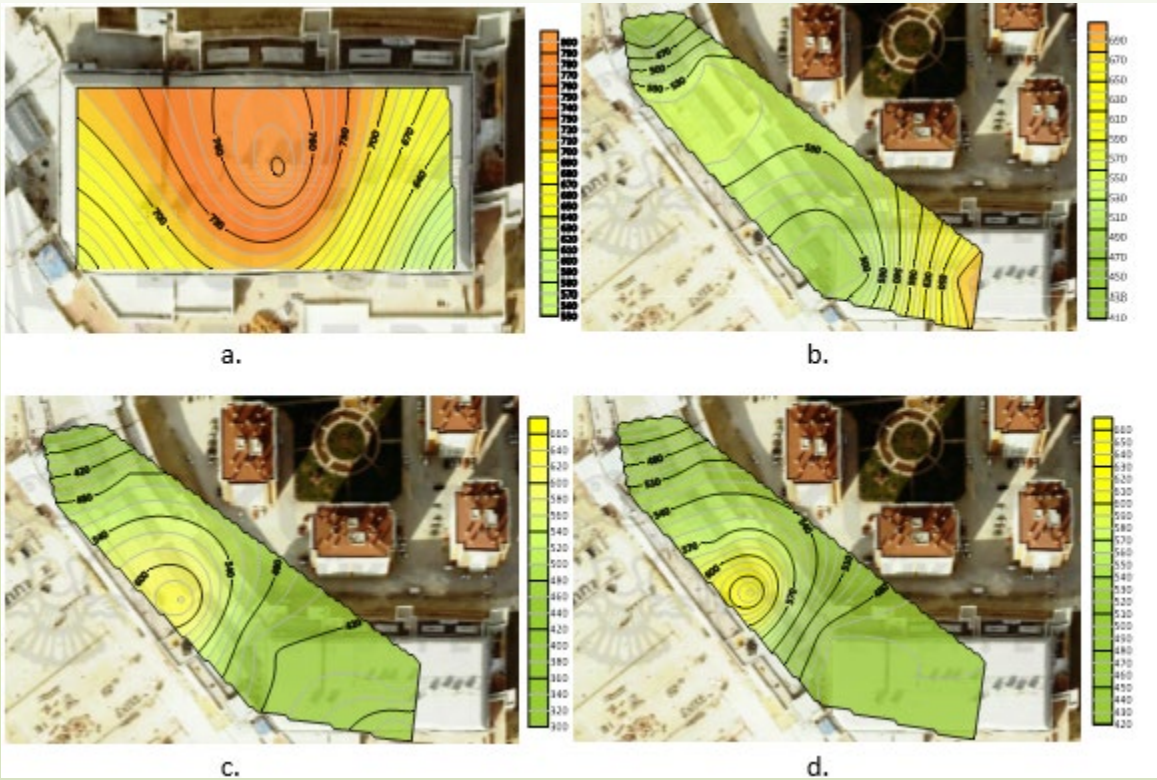


Figure 4.49. Winter season at Novaland AVM on The weekday average (µg/m³) at 17.00 a. (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

- **The weekday results of the measurements made at 17.00 were found as follows: minus 800 µg/m3 for the first layer, (zero) ground layer 690 µg/m3, first layer 660 µg/m3 and second layer 660 µg/m3. The results are similar to the 1:00 PM measurements. Distribution maps of PM2.5 concentrations are shown in Figure 4.49.**

Results and Discussion

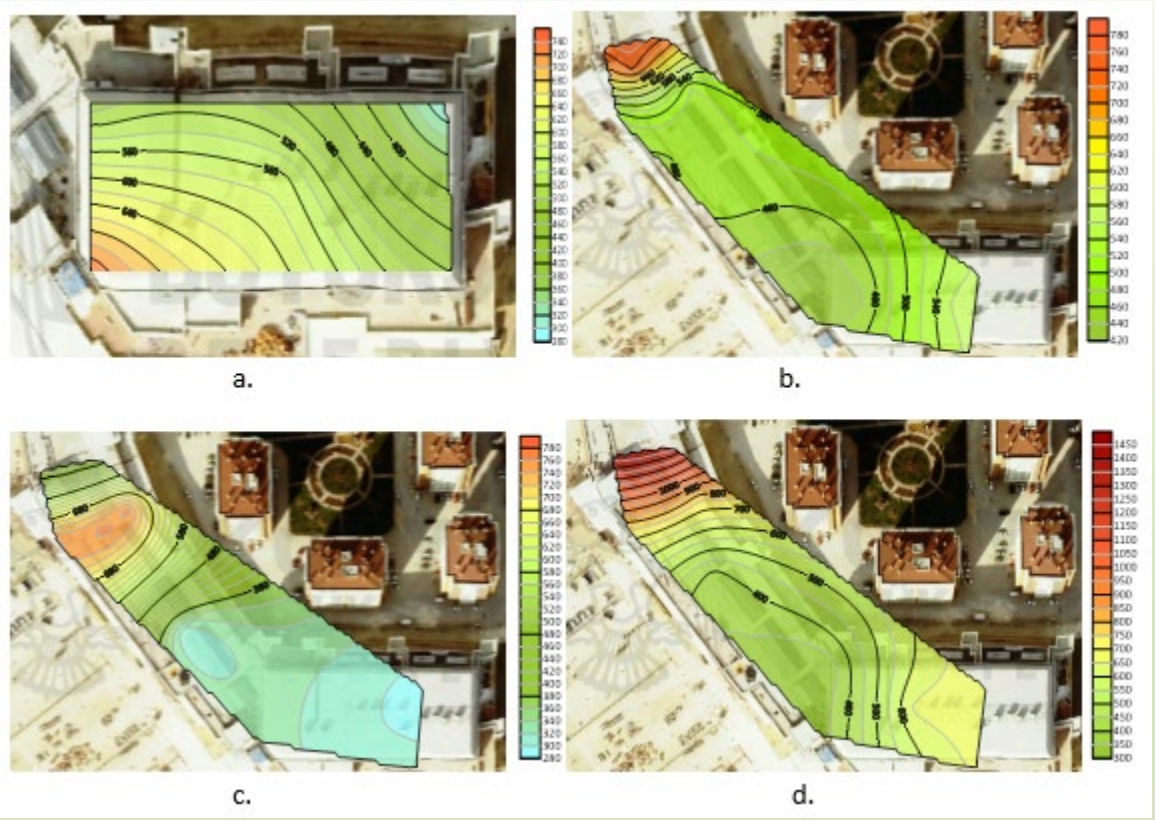


Figure 10. At Novaland AVM, Winter season is at 17.00 on the The weekend average (µg/m^3). (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 17.00 were found as follows: minus the first layer 900 µg/m3, (zero) the ground floor 1000 µg/m3, the first layer 1040 µg/m3 and the second layer 1400 µg/m3. Continuing the pollution effect mentioned at 15.00, it spread to the upper parts of the first floor. The value of 1400 µg/m3 seen on the second floor also showed PM2.5 pollution from the playground. Distribution maps of PM2.5 concentrations are shown in Figure 10.

Results and Discussion

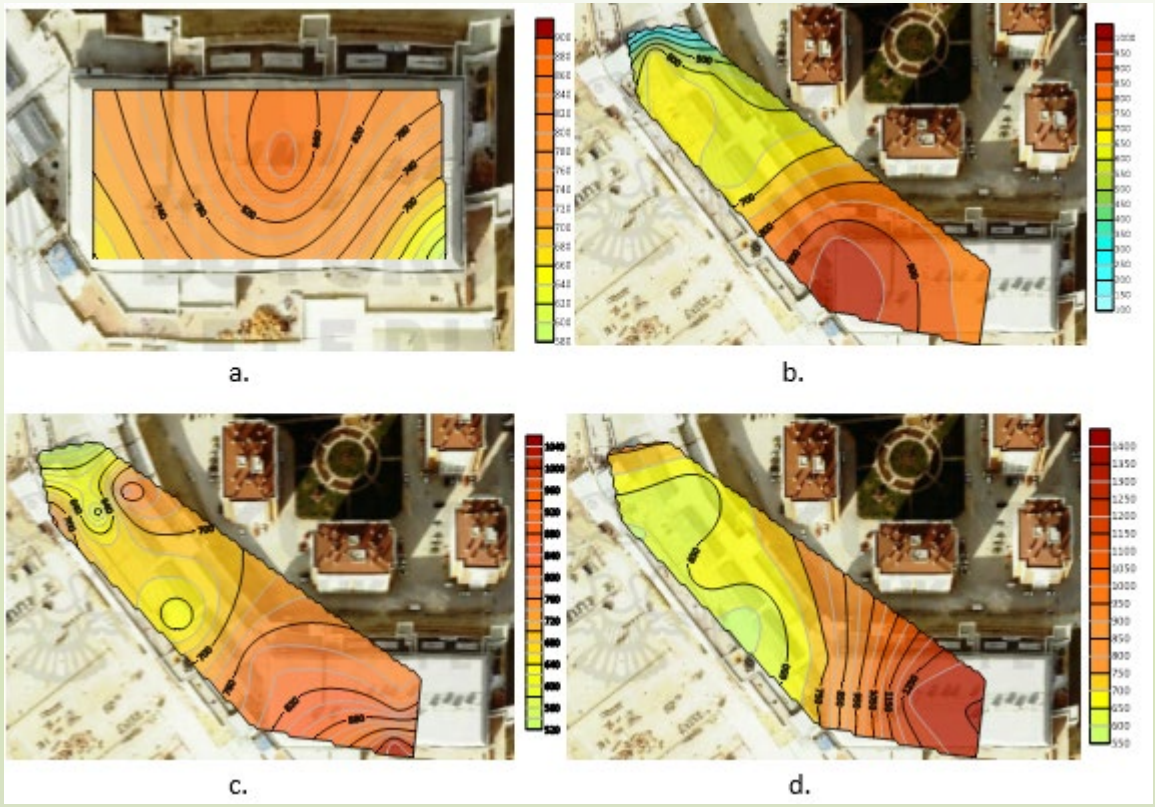


Figure 11. In Novaland AVM, Winter season is at 19.00 a.m. on The average weekday (µg/m³) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

- **The weekday results of the measurements made at 19.00 were found as follows: minus the 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.**

Results and Discussion

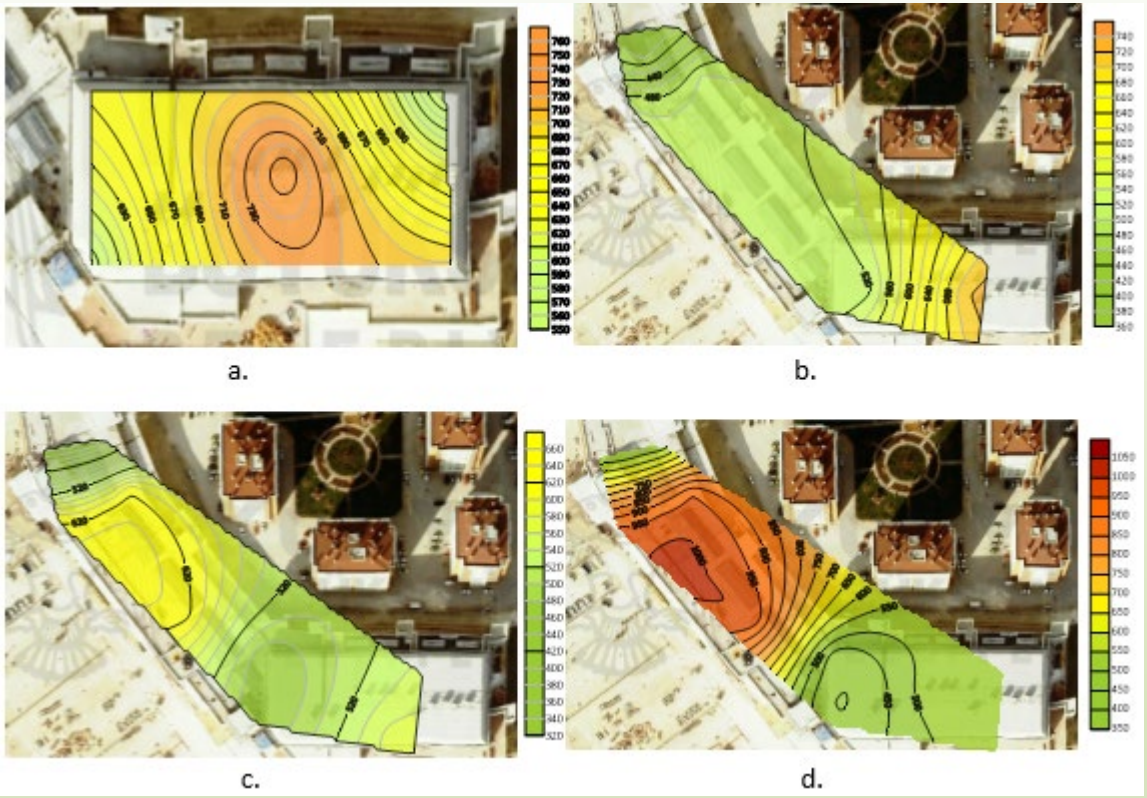


Figure 12. At Novaland AVM at Winter season is at 19.00 a.m. on the The weekend average (µg/m^3) of the autumn season. (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 19.00 were found as follows: minus the first floor 760 µg/m3, (zero) ground floor 740 µg/m3, first floor 660 µg/m3 and second floor 1050 µg/m3. The highest value was seen on the second floor. The fact that the red area corresponds exactly to the point where the restaurants are, showed that the pollution was caused by the cooking activity in the restaurants. In the same area, there is a door to the designated area for smoking. It is thought that cigarette smoke spreads to the indoor environment during the opening and closing of the doors. Distribution maps of PM2.5 concentrations are shown in Figure 12.

Results and Discussion

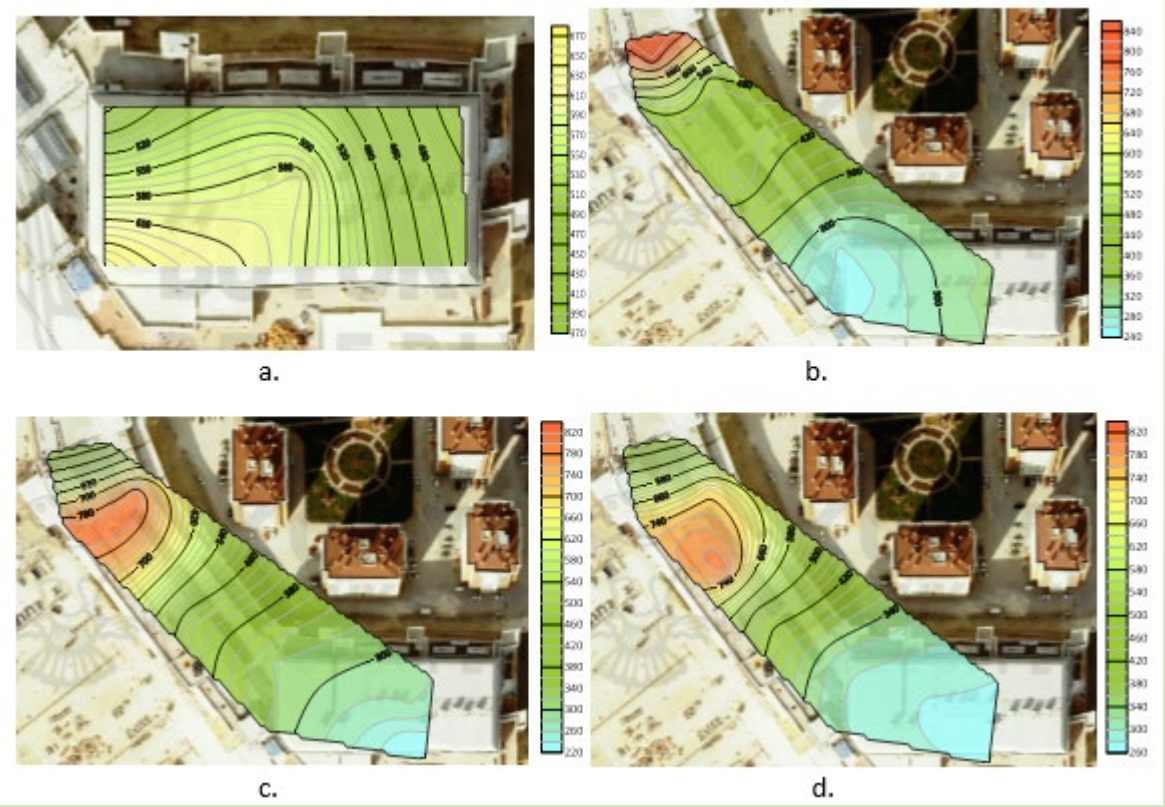


Figure 13. In Novaland AVM, Winter season is at 21.00 a.m. on The weekday average (µg/m^3) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 21:00 were found as follows: minus the first layer was 670 µg/m3, (zero) the ground layer was 840 µg/m3, the first layer was 820 µg/m3 and the second layer was 820 µg/m3. Compared to the previous measurement time, PM2.5 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 PM2.5 concentrations are shown in Figure 13

Results and Discussion

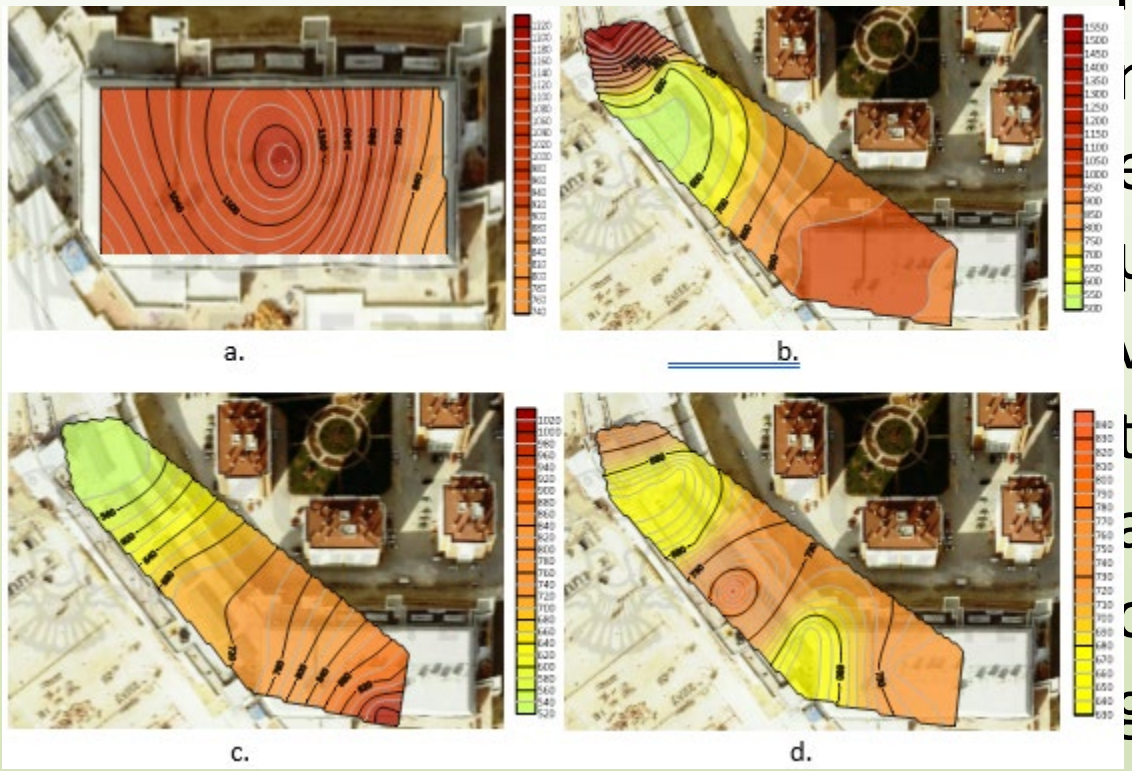


Figure 14. Winter season at Novaland AVM at 21.00 a.m. on the weekdends average (µg/m^3) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 7:00 pm were found as follows: minus the first floor 1220 µg/m3, (zero) entrance layer 1550 µg/m3, first layer 1020 µg/m3 and second layer 840 µg/m3. The values were found to be high in all floors of the shopping mall. While high PM2.5 levels are observed in the areas with the doors opening to the outside environment on the ground floor, high levels are observed in the areas where the playgrounds are on the first floor and in the areas where there are dining, playground and smoking areas on the second floor. Distribution maps of PM2.5 concentrations are shown in Figure 14.

Results and Discussion

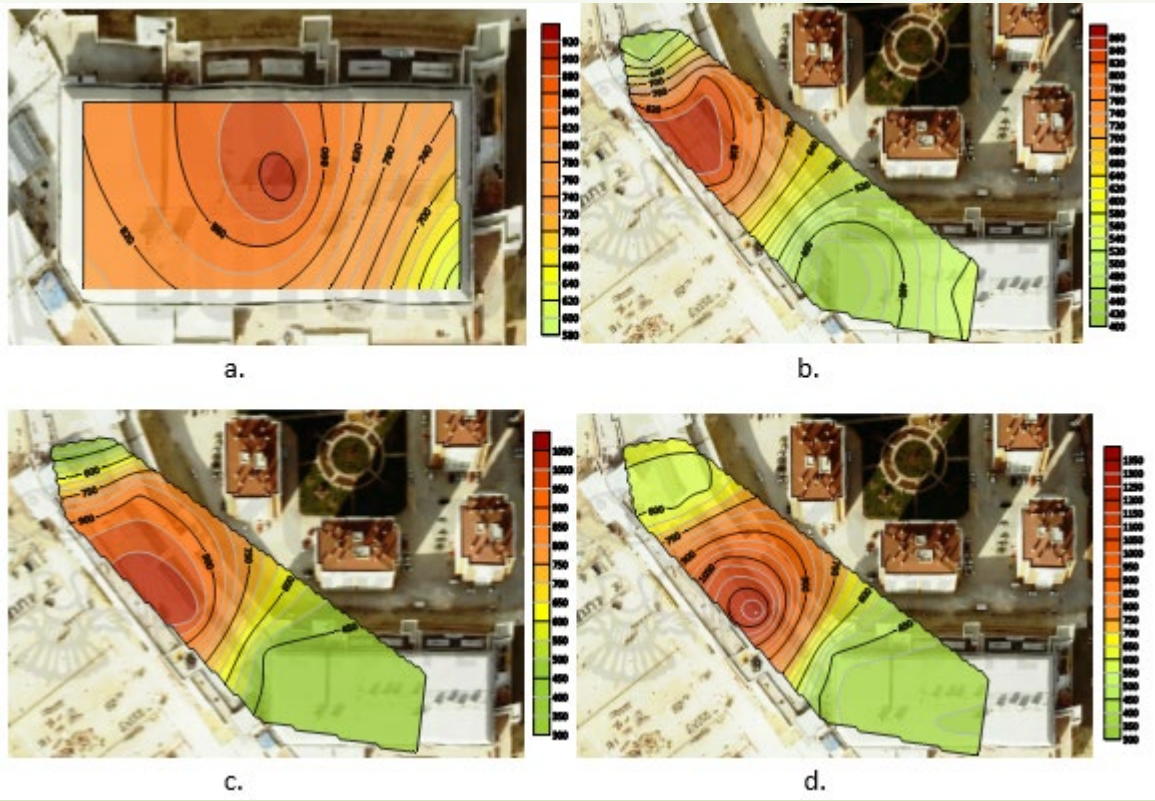


Figure 13. In Novaland AVM, Winter season is at 21.00 a.m. on The weekday average (µg/m³) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekday results of the measurements made at 21:00 were found as follows: minus the first floor was 920 µg/m3, (zero) the ground floor was 860 µg/m3, the first floor was 1050 µg/m3 and the second floor was 1350 µg/m3. PM2,5 concentrations were higher than the results at 19.00. Distribution maps of PM2.5 concentrations are shown in Figure 13

Results and Discussion

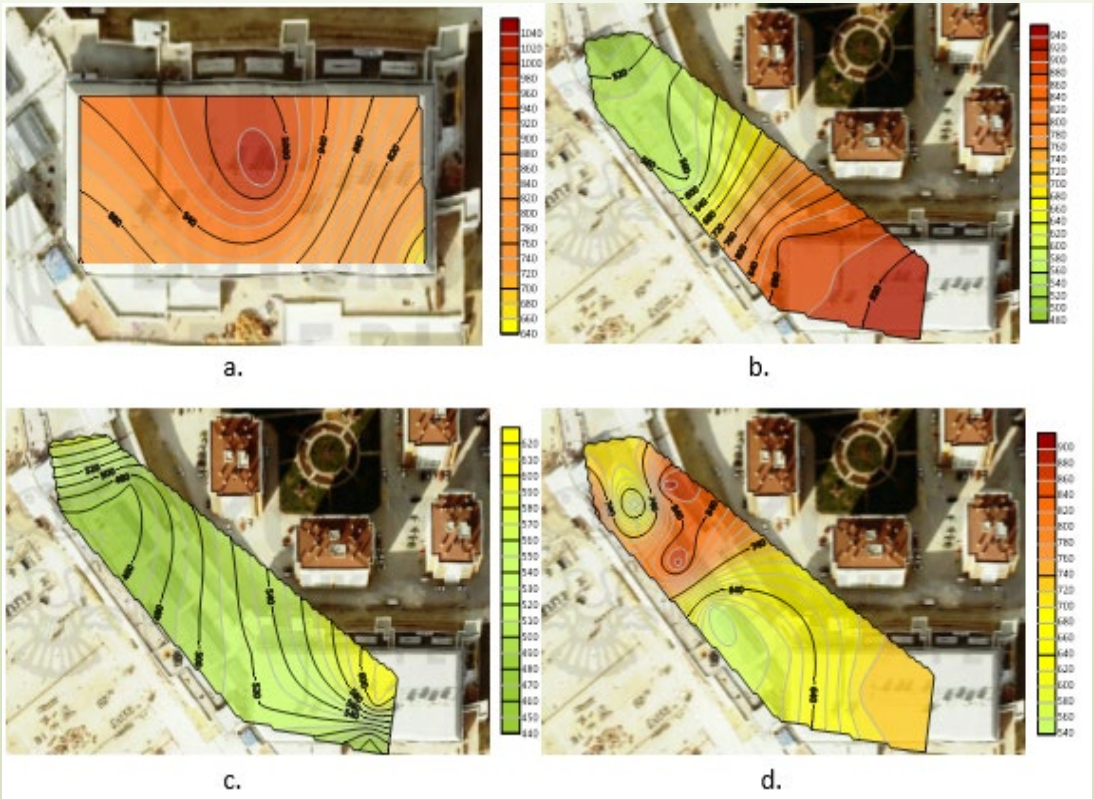


Figure 14. Winter season at Novaland AVM at 21.00 a.m. on the weekdends average (µg/m^3) . (-1) floor, b. (0) floor, c. (1) floor, d. (2) floor average

The weekend results of the measurements made at 21:00 were found as follows: minus the first floor was 1040 µg/m3, (zero) the ground floor was 940 µg/m3, the first floor was 620 µg/m3 and the second layer was 900 µg/m3. The high PM2.5 concentration seen on the minus first floor spread to the ground floor and showed its effect in the lower parts of the building. While the first floor was found to be cleaner in terms of air quality, high levels of PM2.5 pollution were observed on the second floor, only in the area where the restaurants are located. Distribution maps of PM2.5 concentrations are shown in Figure 14.

Results and Discussion

- 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. Two different environments were selected for the measurements. Novada outlet mall was deemed suitable for the second location. 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 $\mu g/m^3$ 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 $\mu g/m^3$. The results obtained exceed the AQCA limit value.

CONCLUSIONS

Lower concentrations were obtained in all three seasons in Novada shopping centre. 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 fact that the measurements made in the summer season coincide with the month of Ramadan caused the results to be lower than the weekend values compared to the weekdays. In the summer period measurements, the situation differed, and the weekend averages were generally higher than the weekday results.

The fact that the concentrations found in Novada mall are lower than that of other males is 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

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 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.

RECOMMENDATIONS

- Also; 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 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 $\mu g/m^3$.
- This value exceeds the hourly 25 $\mu g/m^3$ 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 $\mu g/m^3$.
- The measurable results obtained should be much lower than the APCA limit value (ÇŞ&IDB, 2008), but exceed these values.

REFERENCES

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