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Investigation of the location of an immission measuring point in an urban environment

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Abstract— Life could not exist on Earth without air; this is why its protection is so important. However, air pollution has been known since ancient times, nowadays pollutants from anthropogenic sources occur in much higher quantities. Previously, the primary emission sources were factories due to the industrial revolution, then the development of transportation and the presence of internal-combustion engines made air pollution a major issue. Therefore, more and more efforts have been made over the last decades to reduce the emissions of air pollutants in the industrial sector and the everyday life of the population. Because of this, it is essential to know the factors influencing the air quality of the settlement and to monitor the pollutants properly. Therefore, within the framework of the research work, we examined the possibilities of placing an immission measuring point. To do that, we needed to explore the most important characteristics of the town. Therefore, we examined its structure, meteorological and climatic factors, which fundamentally affect the air quality. We made immission maps using a Geographical Information Program (QGIS) based on the received data. Finally, based on the results, we examined the possibilities of placing an immission measuring station.

Key-words: air pollution, air quality, immission, sensor, particulate matter, QGIS

1. Introduction

In recent decades, environmental protection has become increasingly important to humanity. Within this, the most frequently mentioned topics include water quality protection, soil protection, waste management, wastewater treatment and, last but not least, the protection of ambient air. The atmosphere is made up of gases and liquid and solid particles in different proportions, and the processes between them affect our lives (*Kinney*, 2008; *Kampa* and *Castanas*, 2008; *Gurjar et al*., 2010). From a biological point of view, it is one of the most critical components of our metabolism (*Kim et al.*, 2013), so its protection plays an extremely important role. The appearance of air pollution dates back a long time; it can be linked to man's appearance; it has been known in the form of smoke since ancient times (*Anderson*, 2009). In the 1700s, densely populated large cities were created due to the industrial revolution, making air pollution an increasing problem compared to the past (*Stevens et al*., 2020; *Ghirga*, 2021). However, the emissions are not yet considered significant compared to the current ones. The development of industry, and transport is much more defining and influencing air quality today (*Briggs et al*., 2000; *Krämer et al*., 2000; *Tang* and *Wang*, 2007). These are collectively referred to as anthropogenic sources.

The amount and type of artificial air pollutants emitted into the atmosphere may vary from country to country, depending, among other things, on the amount produced by industrial activity; modernity of the equipment used; type of fuel; degree of removal of contaminants; population; climate; and, last but not least, age, number, and technical adequacy of motor vehicles (*Aunan* and *Wang*, 2014; *Xu et al*., 2018; *Wang et al*., 2020). However, the leading causes of air pollution in urban areas are hazardous pollutants of anthropogenic origin, such as carbon monoxide, sulfur dioxide, nitrogen oxides, ozone, and particulate matter (*Chenet al.,* 2007; *Orellano et al.,* 2020). Our research focused on airborne dust pollution (PM_{10}, $PM_{2.5}$). They are often catalogued as 'floating dust' but are best known as particulate matter (PM), linked with most pulmonary and cardiac-associated morbidity and mortality (*Al-Hemoud et al*., 2018; *Pope et al.,* 1991; *Lu et al.,* 2015). In addition, long-term exposure to current ambient PM concentrations may lead to a marked reduction in life expectancy (*van Zelm et al.,* 2008; *Khaniabadi et al.,* 2016).

The air quality of the settlement is the result of interactions of natural and anthropogenic factors. With the continuous strengthening of environmental awareness, the population became increasingly interested in their living environment, especially the quality of the ambient air. Automatic monitoring stations are now installed almost everywhere globally to monitor the amount of pollutants in the atmosphere and inform the inhabitants of the settlement about the air quality. As the study area is a dynamically developing settlement, it may be necessary to locate a measuring station. Although the population data do not justify this, it can be a reasonable basis for settlement development and planning decisions. In addition, it can help to prepare smog alarm plans and monitor the relationship between the air quality of the settlement and the health of the population.

2. Methodology

2.1. Study area

Balatonalmádi is located on the northern shore of Lake Balaton, about 8 km long, in the southern part of Veszprém county. It has an area of 49.88 km^2, 9,823 people (2019) and a population density of 197 people/km^2 ("Balatonalmádi population, population, area", 2022). The inner area is 759.89 ha, which can be said to be large, and the size of the holiday zone is over 294 ha (KD-ITS Konzorcium, 2015). The city is bordered on the east by Lake Balaton and the north by the Transdanubia Mountains. The topographic conditions played a decisive role in forming the settlement structure, and in some respects, they indicate the boundaries of the city districts.

The settlement consists of four parts of the city, which have different functions due to their character. The largest of them is the city center (called Almádi district), where most town institutions are located. In addition to the administrative function, a significant part of trade and hospitality is there. In addition, there is a considerable amount of residential and recreational area in this area. Due to the railway line separating the coastal strip from the city district there is direct connection between the two areas. The Budatava district officially belongs to Balatonalmádi, but it can be considered an independent district due to its structure and use. It has a unique structure that results from performing different functions. In the area, you will find a single-family residential neighbourhood, four-storey residential buildings, commercial units, a high school, and a site related to urban management. Budatava has many accessible areas that can be used for various functions ("Balatonalmádi", 2022). Vörösberény district was formerly an independent settlement, retaining some of its independence even after its merger with Balatonalmádi in 1971 (*Kredics* and *Lichtneckert,* 1995). In this part of the settlement, there are mostly residential areas, the center of the district is the Veszprémi road and the Ady Endre street. Here you will find the indispensable institutions of city life, such as the post office, GP surgeries, kindergartens, commercial units, and the house of culture. In terms of the nature of Káptalanfüred district, it is the most recreational area; the permanent population is 4% of the city's total population. The proportion of green and wooded areas is higher here than in the rest of the town. In addition to the forested areas, the natural value of Lake Köcsi and the coastal reeds is high.

2.2. Meteorological characteristics, green areas

The climate corresponds to the Hungarian average, usually warm and moderately dry. The number of hours of sunshine per year exceeds 2000, 800–810 hours in summer and only 190 hours in winter. The average annual temperature also corresponds to the climate and the general characteristics of the country (10.2–10.5 ° C), which is around 16.5–16.8 °C in summer (KD-ITS Konzorcium, 2015). The annual rainfall is 580–600 mm, above the national average of 567 mm. The prevailing wind direction is northern, with an average wind speed of 3 m/s, also in line with the national average. Overall, the climate is favorable for frost-sensitive arable crops and vine and fruit production. Its climatic potential offers outstanding tourism opportunities.

In terms of the hydrography of the area, Lake Balaton is dominant, as are the Vörösberényi Séd (5.4 km) and the Remete stream (2.5 km). Lake Köcsi in Káptalanfüred is a temporary lake.

The proportion of the green areas of Balatonalmádi (60 604 m^2) is low compared to the neighboring settlements. Peripheral forests cover more than 300 ha and contribute to improving the environment. Most public parks are located on the shores of Lake Balaton and in the central part of the city. In contrast, Vörösberény and Káptalanfüred contain less green space, which is due to the formation of the structure of the city districts. In Balatonalmádi, the number of rows of trees is typically low, and the location of the existing inland green areas is island-like. The preservation of forest patches on the vineyards is a priority due to the development of the future vision of the settlement.

2.3. Primary pollution source - traffic characteristics

Balatonalmádi can be called a sleeping town; the number of people who commute from the settlement is typically high. However, because the city is a tourist center, it increases 1.5–2 times during the summer. According to the data of the Central Statistical Office, in 2016, a total of 46,746 guests spent at least one night in the town ("Hungarian Central Statistical Office", 2022). The main road (highway 71) connecting Balatonvilágos with Keszthely passes through the city, handling significant tourist traffic. Although there is no direct connection to the expressway network, the M7 motorway can be reached at Balatonvilágos, 25 km from Balatonalmádi. The street view of Vörösberény and Öreghegy adapted to the topography. In contrast, in the case of Budatava and Káptalanfüred, the street system is more regular and designed. Most of the municipal roads are built, their general condition can be said to be adequate.

There are three traffic light junctions and nine railway crossings in the city. The low number of pedestrian crossings is a problem, making it difficult to cross due to increased traffic. The figure below (*Fig. 1*) shows the traffic situation in the town. Significant congestion usually occurs at two traffic light junctions, both are is located on the main road.

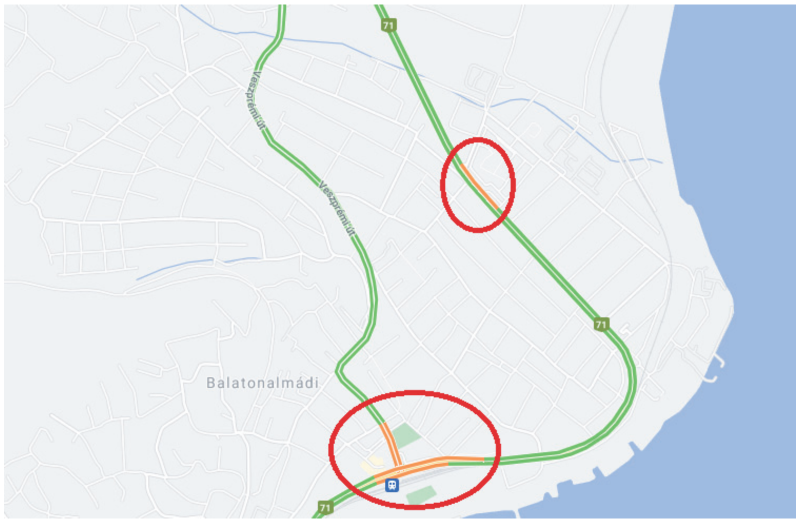

Fig. 1. The traffic situation in Balatonalmádi (source: Google Traffic Monitor)

The increased number of vehicles makes it increasingly difficult to park in the city (*Fig. 2*), especially during the summer months. However, car parks are on the beaches, in the city center, at the municipality and commercial facilities, all free of charge.

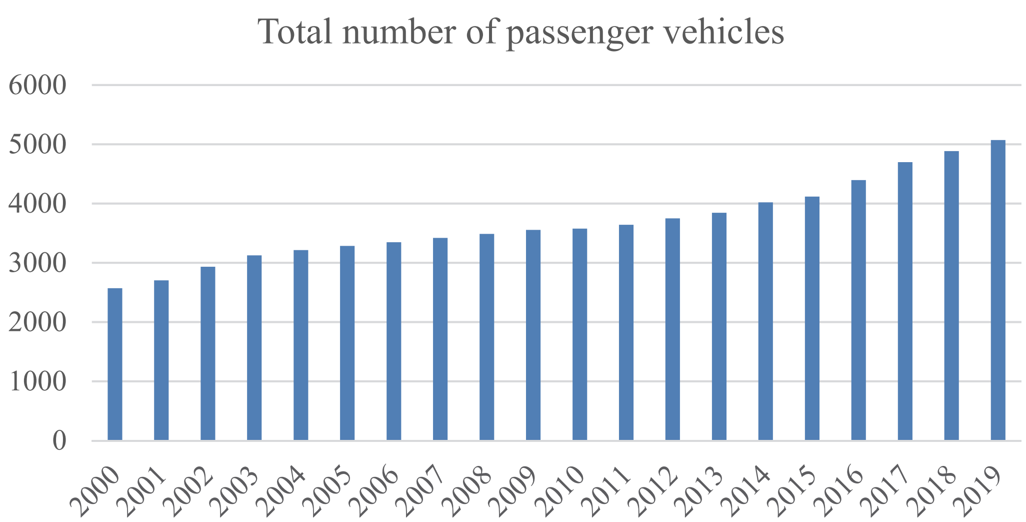

Fig. 2. Number of passenger vehicles in Balatonalmádi 2010-2019 (Source: in Hungarian Statistical Office)

2.4. *The air quality of the settlement*

The National Air Pollution Measurement Network operates a manual measuring station in the settlement (Bajcsy-Zsilinszky út 20.). Data on sulfur dioxide, settling dust and nitrogen dioxide have been available for this station since 2002. However, from 2006, only NO2 was measured at the measuring station ("OLM - Rólunk", 2022; "OLM - Manuális mérőhálózat", 2022). Based on the available data, the air quality of the settlement was good in each of the years. The problem with the manual measuring station is that it is not always possible to operate it continuously; longer or shorter periods of missing data can occur. As a result, the use of installed automatic measuring stations is more appropriate, especially in areas where significant, persistent air pollution can be expected. Alternatively, the daily fluctuations in pollution can be better monitored.

2.5. *The instrument used for measurements*

We measured the air pollution with a sensor called Laser $PM_{2.5}$ Sensor (*Fig. 3*). This laser sensor is suitable for measuring both $PM_{2.5}$ and PM_{10} fractions. The measuring range for both components is 0–999 μg/m^3. The principle of operation of the laser sensor is the following. The passage of particles through a detector results in the scattering of light converted into an electrical signal. This electrical signal is amplified by an amplifier and processed. The signal waveform depends on the number and size of the particles obtained during the analysis ("Laser $PM_{2.5}$ Sensor Specification", 2022). The technical parameters of the sensor used are shown in *Table 1*.

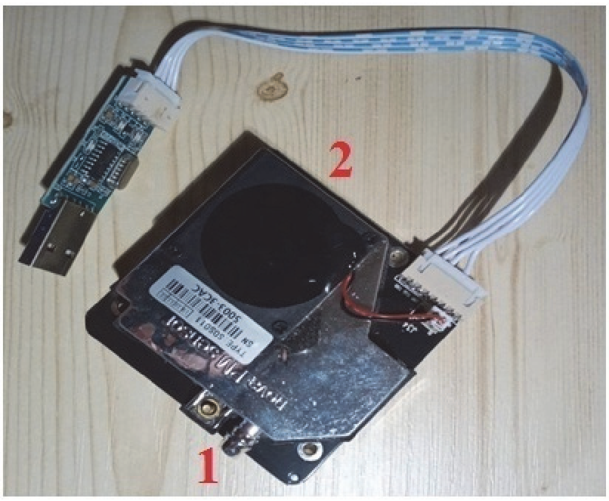

Fig. 3. The sensor used for measurements - The air is introduced at pipe marked with and the outlet at the fan is marked with 2.

Table 1. Technical data of the measuring instrument

Property	Sensor
Measured parameters	PM_{10}, $PM_{2,5}$
Measuring range	0,0-999,9 μg/m^3
Operating voltage	5 V
Operating current	70 mA ± 10 mA
Temperature range (during measurement)	-10 – 50 °C
Humidity (during measurement)	Max 70%
Pressure	86 kPa – 110 kPa
Setup time	1 s
Relative error	Max 15% 10 μg/m^3 esetén
Size	71×70×23 mm

3. Measurements and results

The measurements were performed on foot along dedicated routes in Balatonalmádi in two periods: in March 30 – April 11 and June 1–10 in 2021, almost every day between 7–8 in the morning and 16–17 in the afternoon. The primary purpose of choosing the date was to assess air pollution caused by peak traffic. We used a mobile phone application (Caynax GPS Sport Tracker) to record the routes, GPS coordinates, and time. When choosing the routes, we tried to give a good illustration of the air load caused by the busier areas, but at the same time, we would form a comprehensive picture of the air pollution of the largest possible area. The measurements were performed in Almádi, Budatava, and Vörösberény districts. As Káptalanfüred district is primarily a resort area, we did not examine that area during the measurements.

The measured values were recorded with a free downloadable program called DustSensorViewer v1.3. We set the sampling frequency to 1 minute with the program, which was the lowest value. From the measurement results, we calculated an average of the three routes for each day, which was plotted on the X-axis, showing the date of the measurement and the concentration in μg/m^3 on the Y-axis.

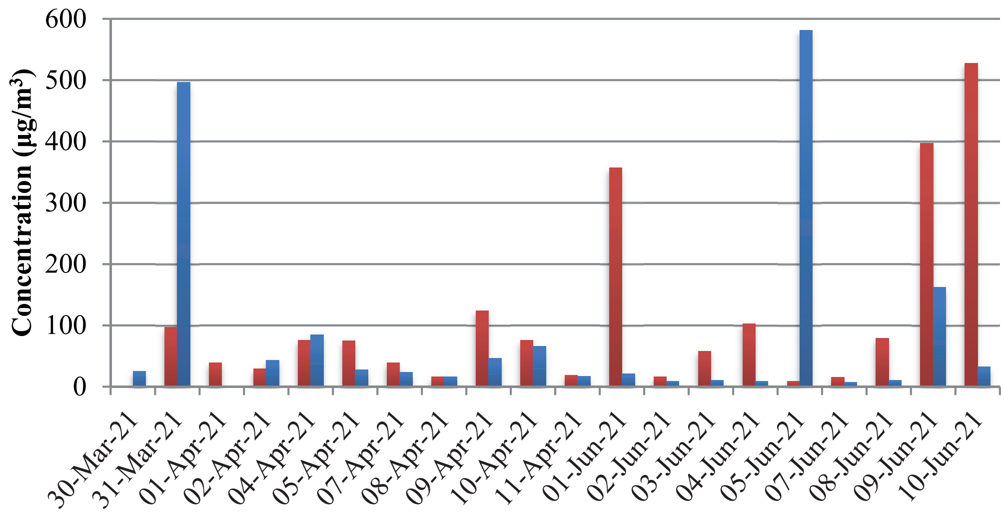

Fig. 4. Average PM_{10} concentrations in Balatonalmádi, Budatava, and Vörösberény districts (red: morning, blue: afternoon).

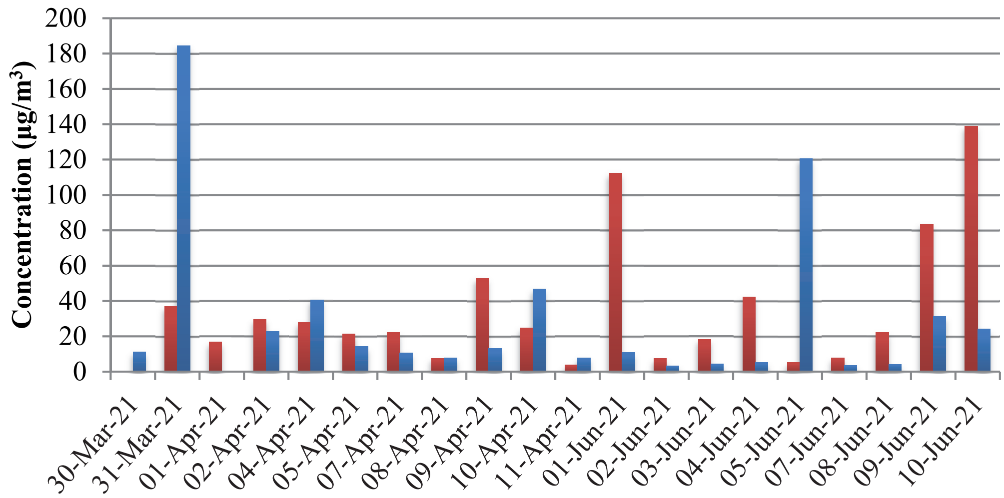

Fig. 5. Average $PM_{2.5}$ concentrations in Balatonalmádi, Budatava, and Vörösberény districts (red: morning, blue: afternoon).

Higher values for both fractions were detected in the morning (*Figs. 4* and *5*). The obtained results were lower than expected, according to which the concentration of airborne dust in the air is higher in the winter heating period. Compared to this, we observed persistently higher values during the measurements in June, which can be traced back to traffic and the release of pollen into the air. The higher values in June may also be explained by the April measurements taken during the closures due to the COVID-19 epidemic, when the schools were closed.

The results were plotted using an open-source GIS program called Quantum GIS 3.18.3. [38] First, we exported the GPS coordinates of the measurement routes from the application as a GPX file and then added this to the map as a new vector layer in the QGIS GIS program for map representation. We loaded the Open Street Map using the QuickMapServices module. Subsequently, the measured PM_{10} and $PM_{2.5}$ concentration values were assigned to the coordinates in $\mu g/m^3$, and the new layer was saved as an "shp" file. Then, the particulate dust concentrations were mapped using the inverse distance weighting (IDW) method. This is based on the fact that the weighting varies inversely with distance. On the resulting map, we set the display to "Palette / Custom Values" for the properties and the "Duplicate" function for the blending mode. Thus, the higher concentration values are displayed in red, while the lower ones are shown in blue, and the measurement paths and the base map are visible. We provided the finished maps with a scale, direction sign and legend.

In terms of all measurements, the concentration of particulate matter was remarkably high during the afternoon measurements, as shown in *Fig. 6*. Furthermore, the highest air load was on the Veszprém road section of the measurement route instead of the main road (highway 71) with generally higher road traffic. A similar distribution can be observed for $PM_{2.5}$.

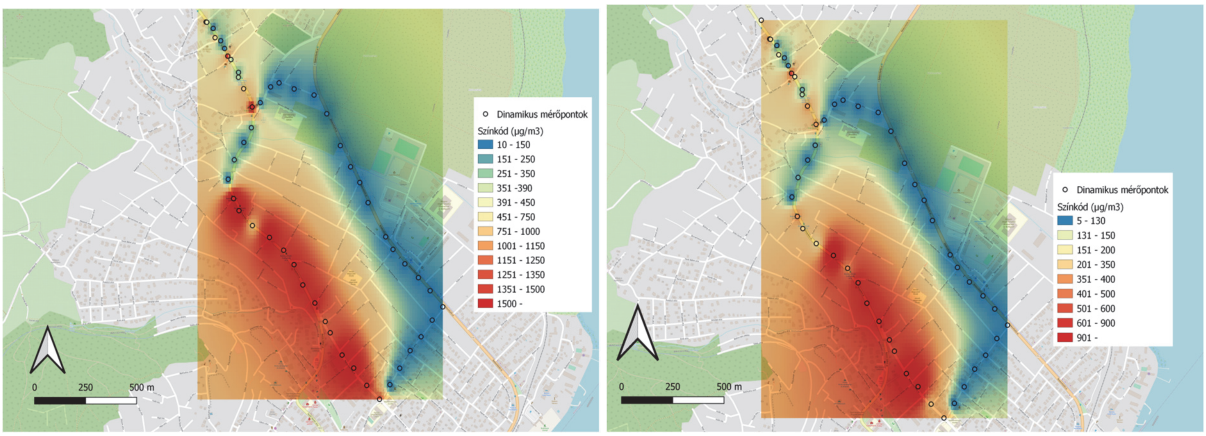

Fig. 6. PM_{10} (left) and $PM_{2.5}$ (right) measurement results of the most polluted day (afternoon of March 31, 2021).

During the morning measurement on April 4 (*Fig. 7*), the environment of Veszprém road was again more exposed to air pollution. The highest values were found on highway 71 Veszprém Road and measured at the intersection of Thököly út, connecting it with the main road. There is a lot of traffic at this intersection every day.

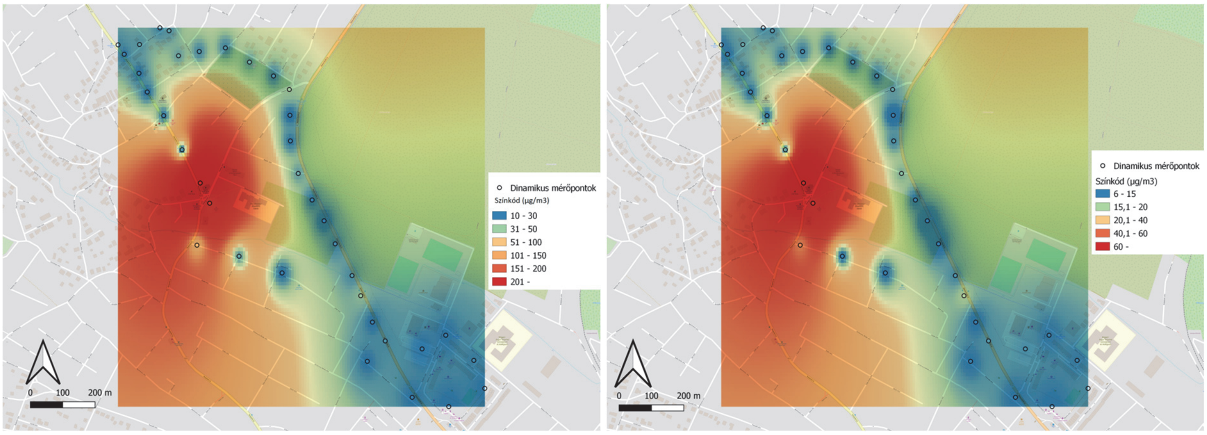

Fig. 7. PM_{10} (left) and $PM_{2.5}$ (right) concentrations in the morning of April 4, 2021.

In the afternoon measurement on April 5 (*Fig. 8*), unlike the previous ones, the highest immission was measured mainly not on the main routes, but ins típically single lane narrow streets whose small width contribute to higher concentraions. In the case of Balázs Béla street, where the air pollution was the highest, the topography also strongly influences the air quality. The middle section of the road lies in a kind of valley, and towards its two ends, it is usually bordered by a stone wall on at least one side. This significantly impedes the flow and mixing of air. As the paving of the surrounding streets being inadequate, their pollination is intense as well.

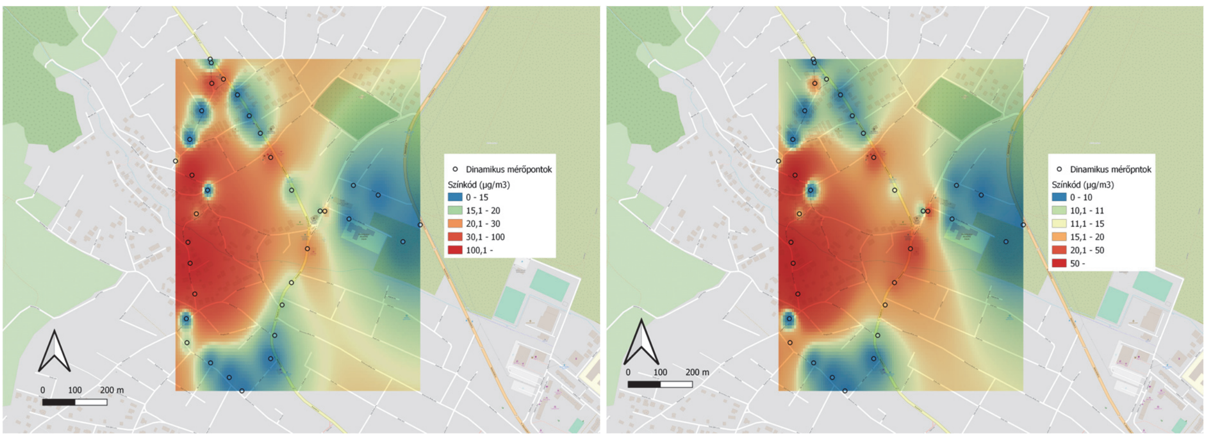

Fig. 8. PM_{10} (left) and $PM_{2.5}$ (right) concentrations in the afternoon of April 5, 2021.

In the case of the third route (*Fig. 9*), unlike the previous examples, the highest air pollution is shown in the vicinity of the main road. This was due to increased road traffic between 7 and 8 p.m.

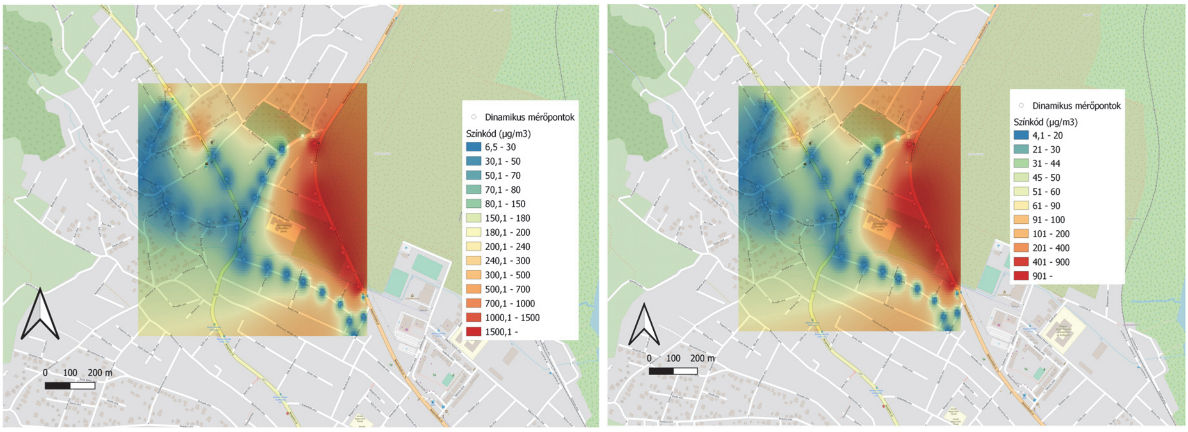

Fig. 9. PM_{10} (left) and $PM_{2.5}$ (right) concentrations in the morning of June 1, 2021.

For the fourth route, the concentration of $PM_{2.5}$ (*Fig. 10*) was also close to the remarkably high concentrations measured at the main road.

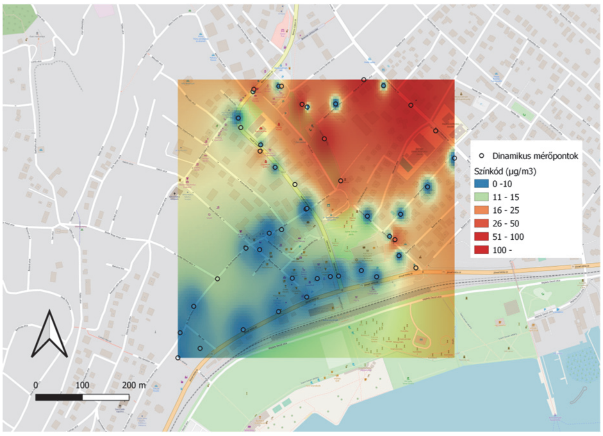

Fig. 10. $PM_{2.5}$ concentration in the morning of June 3, 2021.

4. Discussion – location of the immission measuring station

The immission measuring point must permanently be installed on a ventilated area, so there can be no disturbing landmarks in the environment that obstruct airflow. This condition significantly reduces the amount of suitable regions due to the characteristics of the settlement. In addition, a point must be selected that has no disturbing emission sources or traffic routes within a radius of 100 m. The settlement structure also limits this; the width of the streets does not allow it in several places.

Given the above factors, the best choice for locating an urban background pollution measuring station is a park with enough open space for unobstructed airflow. There are two parks in Balatonalmádi and on the coastal promenade. Of these areas, the waterside promenade is not suitable for the location of the measuring station, as there is significant tourist traffic there, and the visual impact of the measuring station must be taken into account. *Fig. 11* shows the location of the two parks. They are located close to each other at the bus station. For the first time out of the two areas, the Szent István Park may be a better choice in terms of size. The park along the Széchenyi promenade is rather long than wide, and the built-in area is strong here as well, so the airflow is obstructed. In Szent István Park, on the other hand, the air can flow freely around the measuring station, but there the existence of a distance of 100 m from the traffic road is questionable, as the busy bus station is right next to it.

Fig. 11. Investigation of the location of the immission measuring point in Balatonalmádi.

However, an area in the Vörösberény district may suit the measuring station (*Fig. 12*). There is a local primary school close to the main road (highway 71) and there is an open, grassy area between them where air can flow unimpeded. Sufficient distance from the traffic road can also be ensured. However, building a power supply in the area may require more resources than the previous two alternatives.

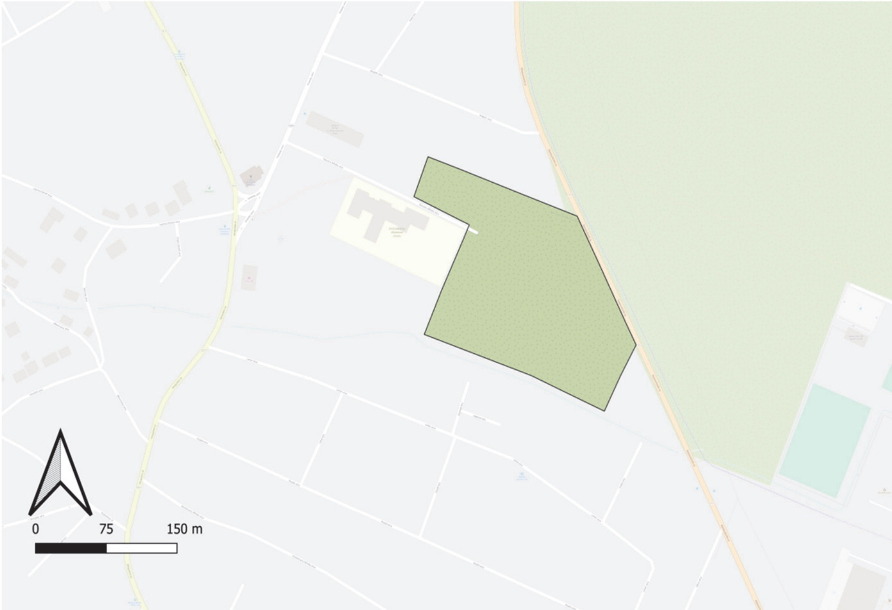

Fig. 12. The proposed area for placing the immission measuring point in Balatonalmádi.

The visible grassy area is currently unused; it is not significant from a tourist point of view, so the deterioration of the view is not a factor in the design of the measuring station. However, we would prioritize the landscaping in case of later utilization, thus creating a buffer zone between the school and the main road.

5. Conclusion

Environmental protection is playing an increasingly important role in our daily lives. In our research, we dealt with air quality protection, and within that with air pollution, its development and monitoring in urban environments. During our work, we mapped the air quality of the city of Balatonalmádi, focusing mainly on particulate matter. The purpose of immission measurement may be to determine the types and concentrations of air pollutants, map the spatial extent and the time course of the pollution, predict the dangerous situation, and search for sources and possible focal points. In addition, it can be used to obtain data during spatial and urban planning, establish official activities (impact assessment, permitting procedure), check the effectiveness of measures aimed at protecting air quality, provide data for scientific activities, and investigate public complaints. We paid special attention to the air pollution of the areas we considered problematic during the immission measurements. These are primarily located in the vicinity of the main transport routes. Furthermore, since several educational institutions are in the settlement, we tried to map their surroundings too. Because of the factors mentioned above, a park with sufficient open space for the unobstructed airflow seemed to be the best choice for locating an urban background station.

We have previously stated that the concentration of airborne dust is highly dependent on traffic and road traffic. For this reason, the widespread use of more modern, more environmentally friendly vehicles is an important goal. To this end, it is necessary to move from petrol and diesel vehicles to more sustainable alternatives like car gas (LPG), hybrid and electric vehicles for both passenger and freight transport. In the case of passenger cars, the construction and promotion of P + R (Park and Ride) car parks can also be adequate. Promoting public transport is also an excellent way to reduce air pollution. For this, of course, the modernization of the vehicle fleet is essential. Providing discounted travel opportunities for the public can also help to promote public transport. In addition, supporting cycling by installation of a rental bike network can improve the air qiality. However, constructing new cycle paths in older built-up areas may be difficult due to the urban structure.

As we have experienced high immissions on several occasions near two educational institutions, it would be essential to intervene in these areas to protect children's health. The main road (highway 71) and the slightly busy but similar Veszprém road pass near the primary school in Vörösberény, which puts a heavy load on the students. There is also a playground next to the school, which is also exposed to a load of flying dust. Afforestation should be used in this area to sequester contaminants. It would be expedient to reduce car traffic in the vicinity of another school in the central part of the town, as afforestation cannot be solved there. There may be a successful competition system among students, the essence of which is that the classes from which most pupils come to school without using a car will be rewarded. In addition to the reform of the transport system, the creation of green spaces and the increase of their size is of paramount importance againtst air pollution. Tree planting in the settlement improves air quality and has a favorable effect on the microclimate, reducing the size of urban heat islands. That could make the town more livable.

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