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ANALYSIS OF CONCENTRATION OF PM_{10} ON THE TERRITORY OF THE CITY OF SOFIA (BULGARIA) FOR THE PERIOD 2017-2020

Milena Simeonova Stefanova

Sofia University ''St. Kliment Ohridski'', Bulgaria
Email: milena.s.stefanova@gmail.com

Abstract

The purpose of the article is to examine, analyze and carry out a geospatial analysis of the quality of the atmospheric air and the concentration of PM_{10} in the city of Sofia for the period 2017-2020. The topic of the atmospheric air quality has been extremely relevant in recent years. The choice of the indicator PM_{10} is due to the fact that the fine dust particles with a size of 10 microns are one of the biggest air pollutants in the city of Sofia. Official data from the Environment Executive Agency was used for the purpose of the study. Through them, a specialized GIS database was created, with the help of which a geospatial analysis of the atmospheric air quality in the capital was created.

Keywords: air quality, PM_{10}, GIS, atmospheric air quality, geospatial analyses

INTRODUCTION

According to the European Environment Agency (*Air quality in Europe report, 2014*) air pollution is a local, European and global problem. Air pollutants released in one country can be carried into the atmosphere, worsening air quality elsewhere. As per EEA the significant proportion of Europe's population lives in areas, particularly in large cities, where permissible air quality standards are exceeded: ozone, nitrogen dioxide and fine particulate matter (PM) pollution, which poses serious health risks to the population. Their accumulation in the environment leads to the formation of fogs, smog and dust. The problem of pollution is often observed in large cities, where there is increased traffic, population concentration and presence of industrial enterprises (*Air quality in Europe report, 2014*). The problem is particularly pronounced in cities located at hollow places (e.g., Sofia) where natural streams cannot flow freely. This leads to air masses retention thus preventing the purification of air in the city.

According to EEA (*Air quality in Europe report, 2014*), the air quality both in the capital - Sofia, and in other European cities is reported to have significantly improved levels. On the one hand, this outcome is due to the introduction of purification plants in the industry, which in the past was one of the most serious polluters. However, air quality has become a serious problem again in recent years.

Air pollution damages human health and the environment we live in. It is mainly caused by industry, transport, energy production and agriculture. As one of the main environmental causes of premature death in the EU, it can lead to cardiovascular and respiratory diseases as well as cause cancer. Air pollution significantly affects healthcare, causing up to 7 million premature deaths per year and even greater numbers of hospitalizations and sick leave days (Orru, H., et al., 2017).

Not all air substances are considered as pollutants. The presence of certain pollutants in atmosphere at levels harmful to human health, to the environment and cultural heritage is considered to be pollution. Air pollution is not only a result of human activity. In addition, many natural phenomena such as volcanic eruptions, forest fires, sandstorms and others release pollutants into the atmospheric air (Curmei, M. & Kurrer, C., 2023).

Despite the improved quality of the ambient air in Europe in recent decades, the aim is to reach levels of unsignificant negative impact on human health and the environment. The air quality standards are often breached, especially in urban areas ('hotspots'), where the majority of Europeans live. The most problematic pollutants currently are the fine particulate matter, nitrogen dioxides and tropospheric ozone (Curmei, M. & Kurrer, C., 2023).

MATERIALS AND METHODS

The most basic and mass pollutant of atmospheric air are the fine dust particles (PM). They pose a potential risk to human health when their level is high. PMs are a serious air quality problem on a global scale. They are composed of solid particles, small water droplets and chemical substances additionally absorbed on their surface (organic compounds, metals, allergens in the form of pollen fragments, molds, spores). The dust aerosols are formed during: natural processes (storms, volcanoes, earthquakes); anthropogenic activities (mining industry, construction, transport, etc.); they can also be formed as a secondary product of chemical processes occurring in the atmosphere.

PMs represent a serious problem for the quality of the atmospheric air in Sofia where excessive concentration of particles is most often observed during the winter months. This is determined by the geographical location of the city.

During the heating season the main source of dust particle pollution is the burning of solid and liquid fuels in households. Low chimneys and the specific weather conditions in the winter season prevent the adequate dispersion of atmospheric pollutants.

According to the Bulgarian legislation (Ordinance No.12) the following norms are regulated for PM_{10}: Average day-night norm for the protection of human health - 50 $\mu g/m^3$ (not to be exceeded more than 35 times a year); Average annual norm for the protection of human health - 40 $\mu g/m^3$.

Application of GIS for the purposes of ambient air quality management

The geographic information systems (GIS) are increasingly popular and applied in the planning and management of territory and regional development. They are a tool for organizing data on territories, they also serve for spatial localization and identification of existing problems, provide methods for analyzing the necessary information to solve problems and challenges. GIS are increasingly used in analysis of atmospheric air quality (Popov, A., 2012).

There are many definitions about the geographic information systems, but in general they can be defined as systems of tools with the help of which geographic (geospatial) data are collected, processed, stored, analyzed and visualized and geographic information is generated (MCDONNELL, KEMP, 1995). They provide a new and more efficient way to process, analyze and visualize information.

GIS are also used to perform spatial analyses. They require in-depth knowledge of the studied phenomena, critical thinking, skills for practical application of various spatial concepts from the field of geoinformatics and other sciences. The results of spatial analyses can be visualized with maps, graphics, animations, text, or with a combination between these representations (Popov, A., 2012).

In recent years, geographic information systems are increasingly used in the management of atmospheric air quality, the preparation of spatial analyses and in the making of adequate management decisions in the field of environmental protection. All maps for the analysis of PM_{10} were created by using the above-described method - IDW interpolation.

Air quality in the city of Sofia

According to experts from Sofiaplan (Vision for Sofia, 2018) one of the most serious pollutants of air quality during winter in Sofia is domestic heating from solid and liquid fuels. There is a lack of reliable information on the number of households and their consumption by types of sources. Data on the quality of fuels used for domestic heating are not collected, therefore domestic heating emissions cannot be accurately calculated, nor can they be spatially distributed on the city map. The available estimates of the share of domestic heating in the total emissions are based on expert opinion and, at best, on indirect estimates, which at this stage provides the most reliable data, but they cannot show the real picture.

According to the assessment made in the Air Quality Management Program at the Municipality of Sofia (2020), PM emissions from domestic combustion for 2014 were estimated at 42% of the total emissions. According to data from the 2011 population Census from NSI, the majority of households in Sofia are heated by the central heating (a thermal power plant and gasification), about ¼ use electricity and only about 12% use solid and liquid fuels, which are the only sources of heating that produce significant emissions of pollutants in the air.

Another significant source influencing the quality of atmospheric air in Sofia is transport. In the Program for Atmospheric Air Quality Management in Sofia Municipality, PM emissions from transport for 2014 were estimated at 57% of all emissions, which indicates transport as the main source of PM pollution in Sofia. Compared to the domestic heating pollution, transport is significantly easier to assess.

For the purposes of the current study, maps were created that show the maximum reported values for PM_{10} by year. The source of the data used is the Environmental Executive Agency (EEA). These are the quarterly bulletins on the state of environment and, more precisely, on air - the levels of main indicators of atmospheric air quality.

According to experts from Sofiaplan (Vision for Sofia, 2018) the largest deviations in the air quality standards are observed during the cold months during the heating season. A prerequisite for the retention of polluted air over the capital is the relief and the climatic features of the studied territory. Due to the specificity of the geographical location of the city, the climatic features also play an important role in the formation of air quality.

RESULTS AND DISCUSSION

According to Ordinance No. 12, the average daily norm for the protection of human health is equal to 50 $\mu g/m^3$, and it should not be exceeded more than 35 times within one calendar year, and the average annual norm for the protection of human health (for one calendar year) is 40 $\mu g/m^3$. From the beginning of the study to the present day, there is no single calendar year in which the indicator was not exceeded significantly more than 35 times, and there was an excess by a quarter for almost all quarters. Despite the significant total number of all exceedances, during the studied period there is a tendency towards a slight decrease in the reported maximum values of PM_{10}, which does not make the air condition better for people, as the values again are significantly above the health protection norm.

Despite the essential importance of the indicator, its evaluation and analysis are extremely difficult and minimized, given the absence of a sufficient number of sensors monitoring its values. For the territory of the city, 6 sensors report data on PM_{10}.

Figures 1, 2, 3 and 4 show the excesses of the indicator in 2017. The maximum value for the year was reported by AMS Hippodrome - 348.82 $\mu g/m^3$, which is the third record value for the entire studied period, followed by AMS Pavlovo with a significantly exceeded norm - 331.98 $\mu g/m^3$, followed by AMS Nadezhda –

293.34 μg/m^3, AMS Mladost – 257.14 μg/m^3 and AMS Druzhba with 238.97 μg/m^3, while for AMS Kopitoto no excesses were reported. During the April-June period, all measuring stations reported on the exceeding of the norms, including AMS Kopitoto, which ranked second in the measured value - 71.79 μg/m^3, preceded only by AMS Nadezhda with 124.39 μg/m^3. The third quarter recorded exceedances for four of the six sensors. The year ended with recorded maximum values from AMS Nadezhda 182.82 μg/m^3, followed by Hippodrome, Pavlovo, Mladost and Druzhba with respectively 140.76 μg/m^3, 136.04 μg/m^3, 116.46 μg/m^3 and 70.06 μg/m^3.

Figures 5, 6, 7 and 8 present the maximum values of PM_{10} for the calendar year 2018. That was the first year since the beginning of the research period with such a small number of exceedances in the summer months - an exceedance was reported by AMS Hippodrome and AMS Nadezhda for the third quarter; and by AMS Hippodrome, AMS Nadezhda and AMS Pavlovo, with the maximum reported values for both quarters being below 70 μg/ m^3. The cold months were again marked by a significant excess of the permissible norms - AMS Mladost reported the highest values in the first and fourth quarters of the year, respectively 259 μg/m^3 and 255.96 μg/m^3. For the period January-March, the excesses were in the range of 81.05 μg/m^3 (Kopitoto) - 259 μg/m^3 (Mladost), and for the period October-December 62.99 μg/m^3 (Kopitoto) - 255.96 μg/m^3 (Mladost).

Figures 9, 10, and 11 show the three quarters of 2019 that exceeded the norms for the PM_{10}. That was the first year for the entire study period in which no excess was registered for the July-September quarter. During the January-March period, for the first time since the beginning of the research, excesses with values below 200 μg/m^3 were reported, the highest being from the AMS Hippodrome - 197.67 μg/m^3, and the Kopitoto sensor did not report any excesses. The second quarter recorded values of excesses below 80 μg/m^3, the highest being for AMS Kopitoto - 77.33 μg/m^3. At the end of the year, the highest values for the indicator were reported from AMS Hippodrome - 226.32 μg/m^3, followed by AMS Nadezhda with 219.54 μg/m^3, AMS Pavlovo with 161 μg/m^3, AMS Mladost with 159 μg/m^3, AMS Druzhba with 117 μg/m^3 and AMS Kopitoto with 87.6 μg/m^3.

Figures 12, 13, 14 and 15 present the indicators' excesses in 2020. During the first part of the year (January-March), the norms were exceeded for each sensor, with values in the range of 82.55 μg/m^3 - 164.94 μg/m^3, respectively for AMS Druzhba and AMS Nadezhda. It is impressive that during this quarter AMS Kopitoto reported higher values than AMS Druzhba - 94.76 μg/m^3. The second quarter of the year was marked by exceedances for five of the six sensors, with values within 56.82 μg/m^3 for AMS Hippodrome and 101.86 μg/m^3 for AMS Kopitoto. The Kopitoto sensor reported the highest value compared to all other sensors. The period July-September marked an excess for only one sensor - Nadezhda, with 67.4 μg/m^3. At the end of the year, there was a jump in the norms for every single sensor, with the exception of AMS Kopitoto. The highest recorded value was from AMS Nadezhda – 218.27 μg/m^3, followed by 152.29 μg/m^3 for AMS Pavlovo, 143.31 μg/m^3 for AMS Hippodrome, 140.31 μg/m^3 for AMS Mladost and 85.62 μg/m^3 for AMS Druzhba.

CONCLUSION

Atmospheric air pollution is one of the major global problems of an extremely large scale that requires the adoption of far-reaching measures. Building a network of sensors to monitor air pollution and locate polluted areas is one of the main measures that countries internationally must take. In this way, accurate and timely information will be provided, according to which specific measures can be taken at local, regional, national and international level to deal with the situation.

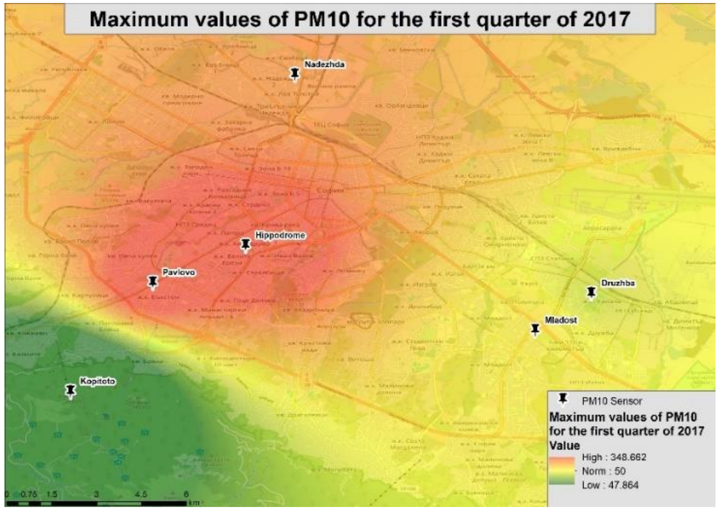

Fig. 1. Maximum values of PM_{10} for the first quarter of 2017.

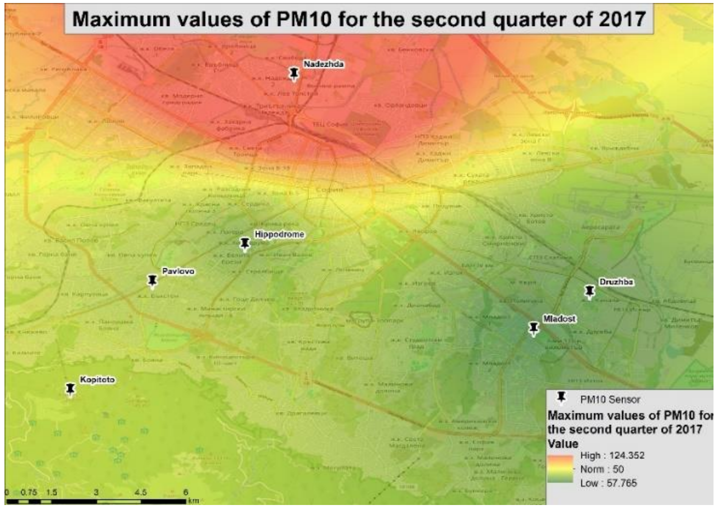

Fig. 2. Maximum values of PM_{10} for the second quarter of 2017.

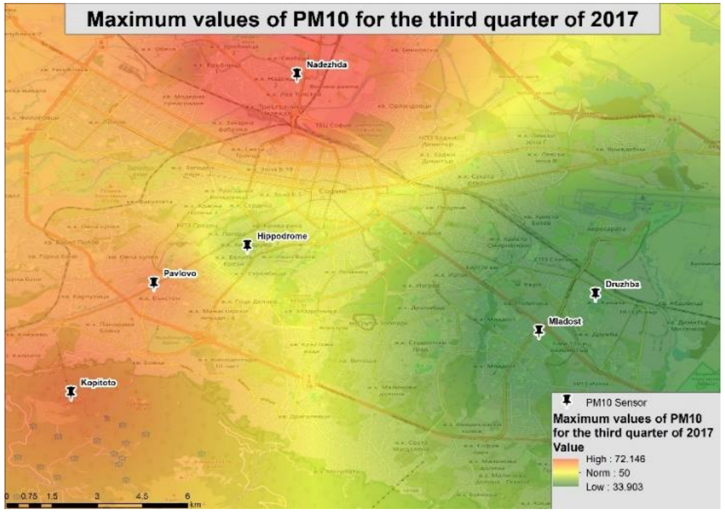

Fig. 3. Maximum values of PM_{10} for the third quarter of 2017.

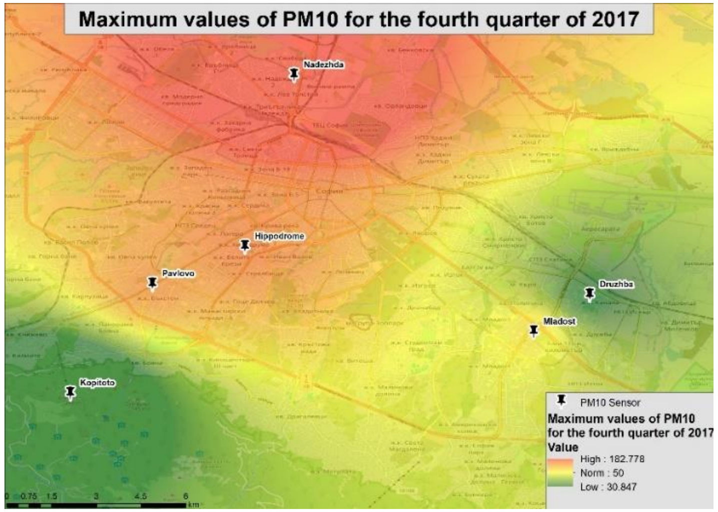

Fig. 4. Maximum values of PM_{10} for the fourth quarter of 2017.

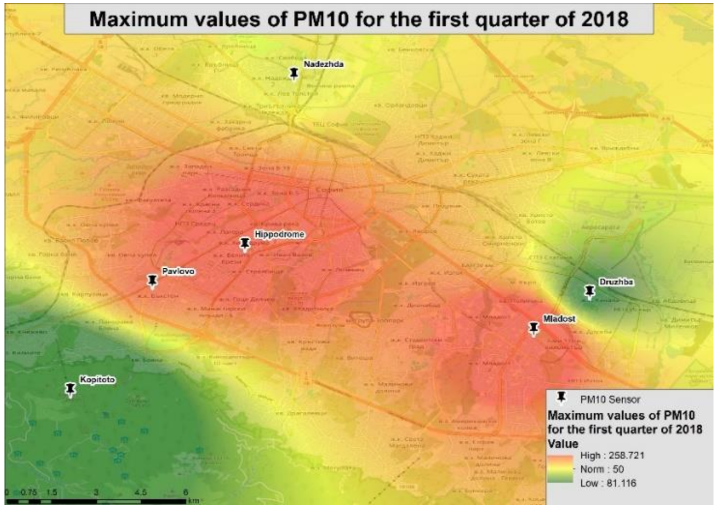

Fig. 5. Maximum values of PM_{10} for the first quarter of 2018.

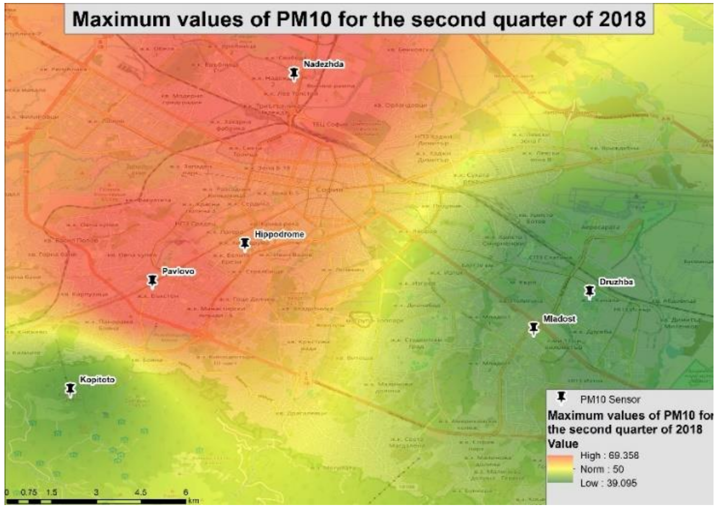

Fig. 6. Maximum values of PM_{10} for the second quarter of 2018.

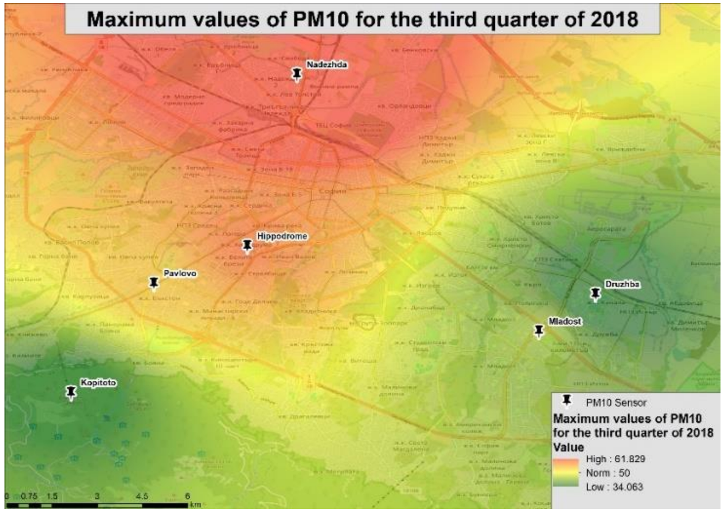

Fig. 7. Maximum values of PM_{10} for the third quarter of 2018.

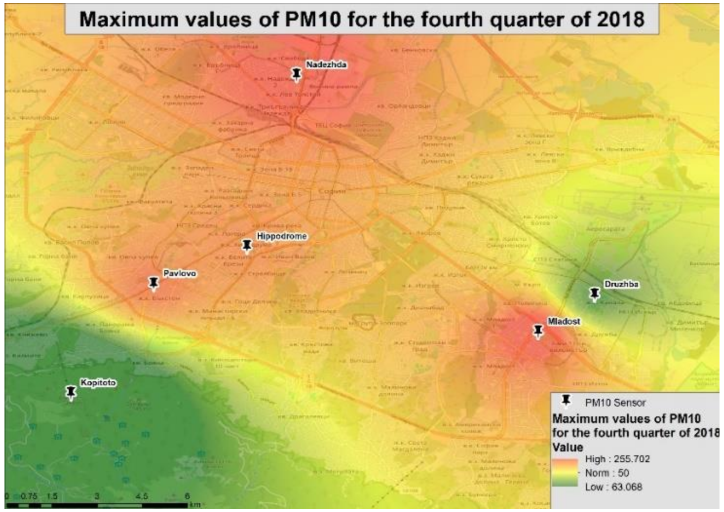

Fig. 8. Maximum values of PM_{10} for the fourth quarter of 2018.

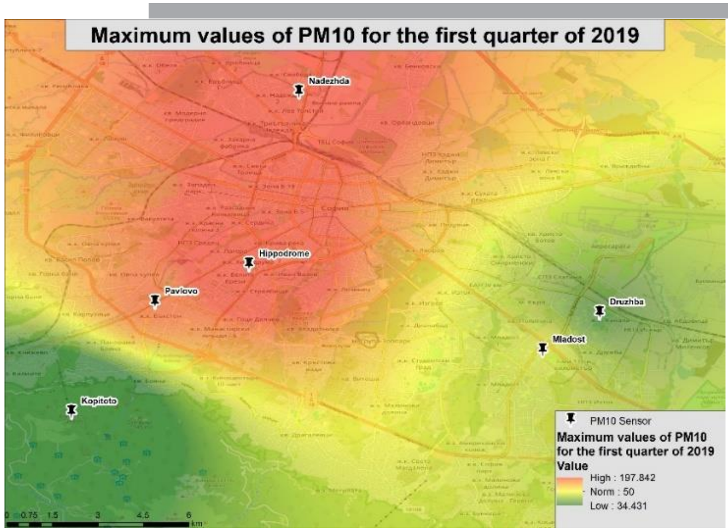

Fig. 9. Maximum values of PM_{10} for the first quarter of 2019.

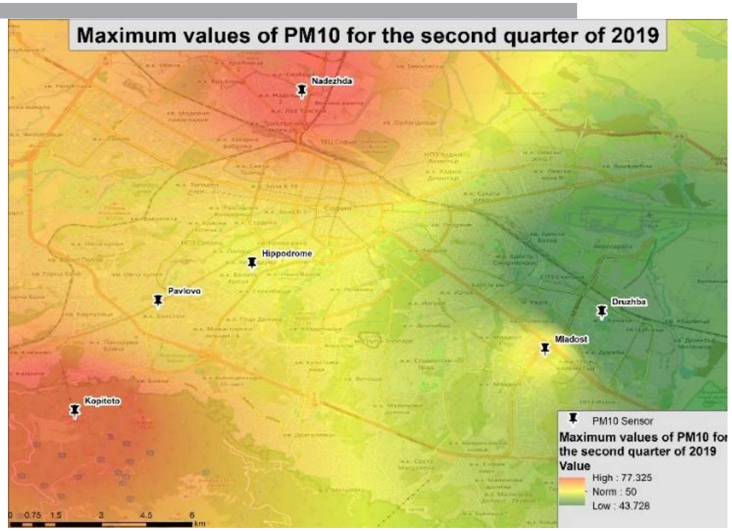

Fig. 10. Maximum values of PM_{10} for the second quarter of 2019.

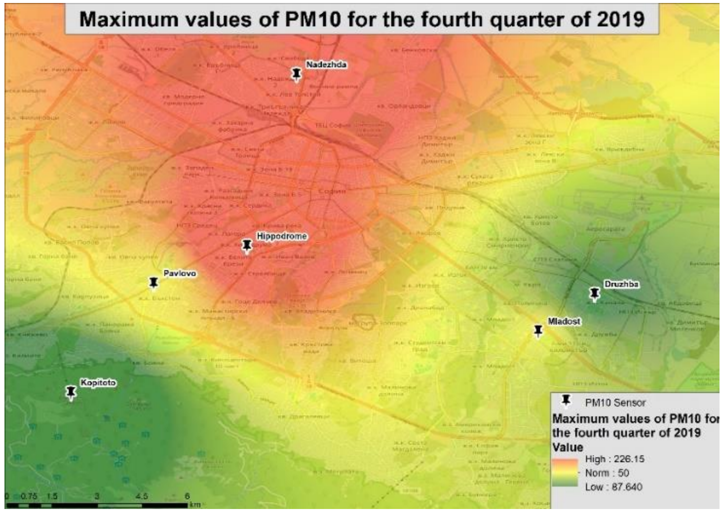

Fig. 11. Maximum values of PM_{10} for the fourth quarter of 2019.

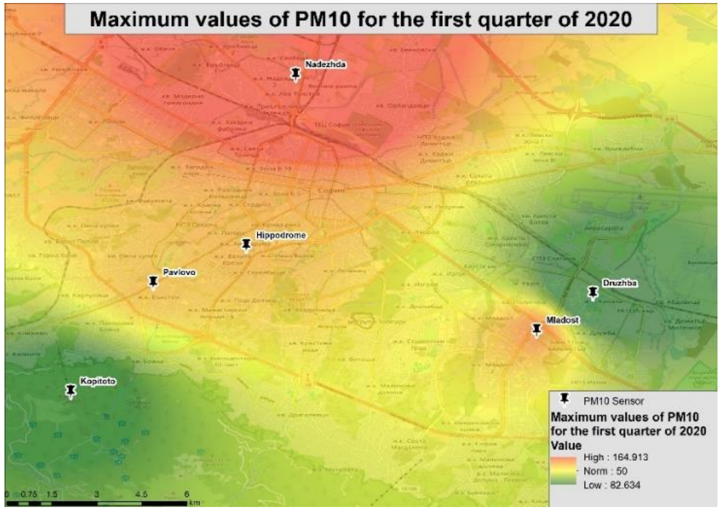

Fig. 12. Maximum values of PM_{10} for the first quarter of 2020.

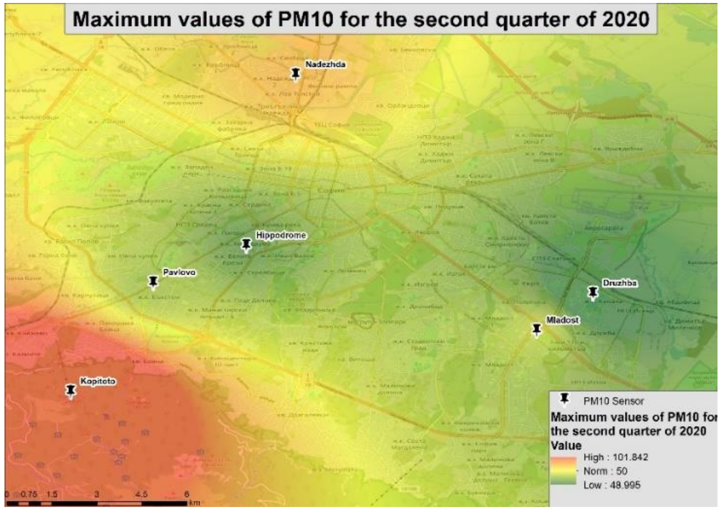

Fig. 13. Maximum values of PM_{10} for the second quarter of 2020.

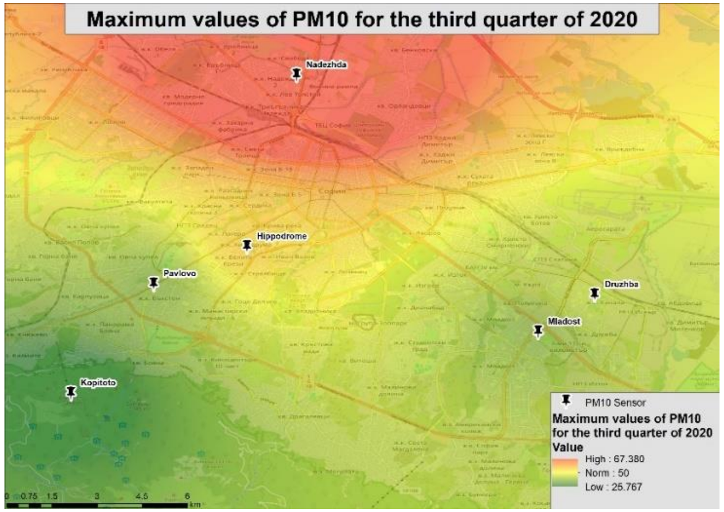

Fig. 14. Maximum values of PM_{10} for the third quarter of 2020.

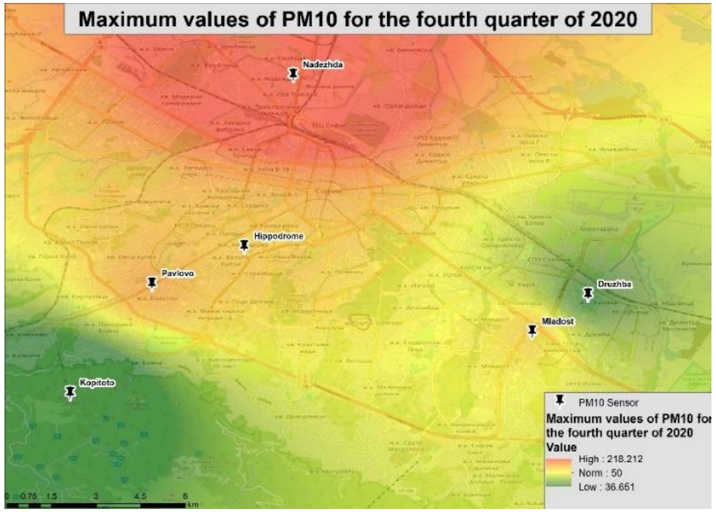

Fig. 15. Maximum values of PM_{10} for the fourth quarter of 2020.

The problem of air quality is very much geographically determined. Especially for Sofia, this is a problem that is partly due to the natural geography, given the fact that the capital is located in a hollow.

The uneven coverage of the EEA sensors across the country, including the capital, makes analyzing the quality of atmospheric air extremely difficult. The sensors that the EEA provides are considered reliable information on the quality of atmospheric air, but there is a need for building a significant number of new devices so that the territory not only of the capital, but also of the entire country is covered; this in turn would lead to more adequate, successful and detailed analyses and studies of atmospheric air pollution. The available information on the emissions by pollution sources is not detailed enough and more data is needed for making sufficiently well-founded analyses on the basis of which the correct and most effective measures can be taken to improve the air in Sofia. The biggest deficiency of the data is perhaps its lack of spatial dimension, i.e., the possibility to associate the different territories in the city with different types of pollutants and degrees of pollution. The available data, on one hand, can still be used to get results, but on the other, the lack of sufficient specific information can doom the measures to failure or low efficiency.

Within the framework of the research, the set goal was fulfilled, namely an analysis of the concentration of PM_{10} for Sofia over the period 2017-2020.

According to experts from Sofiaplan (Vision for Sofia, 2018) the ambient air quality for Sofia has improved significantly, and has continued to improve over the last years. When comparing the indicators from 10 years ago and more, about 30-40% decrease in norms is clearly observed, which shows a positive trend.

Nevertheless, it is necessary that the Municipality undertakes more and more "green" measures to continue the positive trend of recent years. The resolution of the air problem in Sofia needs not only to address the financial effectiveness of related measures, but also find a timely outcome. It is necessary to realize that we all live together in this city and the daily decisions of each of us affect everyone, including ourselves.

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