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An approach to using the AQI components in urban air pollution sources identifying

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ABSTRACT

Problem statement. The fact that the air we breathe is polluted is well known. There are many sources of pollution, especially in big cities. Various sensors are installed to monitor pollutants in the air. One of the global systems for registering the concentration of pollutants in urban air is AQI. Air quality monitors collect data of five major air pollutants – ground-level ozone, particle pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide, that then convert to the Air Quality Index. And although the sensors themselves are not capable of reducing pollution in the air, based on the data they provide, it is possible to create indicative maps of urban pollution. Such mapping of urban areas will enable authorities to develop and implement plans to improve the most dangerous areas, as is already done in other countries. But there are still no such maps for Kyiv.

Study objective is to analyse the air quality index in Kyiv, identify the main source of atmospheric pollution and to visualize urban air pollution.

Methodology involves data analysis from 15 sensors of the AQI worldwide network. We analyzed the concentration of 5 main air pollutants contributed to the common Air Quality Index for a certain period in Kyiv and its surroundings. Knowing the exact coordinates of each sensor and the results of their measurements, we drew a map of air pollution in Kyiv using OriginPro 8.1 software and images from the Google maps.

Research results. It was determined that the largest contribution to the Air Quality Index is made by the fine particulate matter emissions. We determined that the morning sensor data on the amount of dust in the air is the most informative. It is known transportation is one of the main sources of $PM_{2.5}$ in the city. Our map clearly shows that the area with the highest AQI value coincides with a major road junction on the north-west outskirts of the city. Thus, atmospheric pollution in Kyiv is mainly determined by the amount of fine dust in the air. Further research will be aimed at identifying the relationship between the amount of $PM_{2.5}$ in the air and the morphological parameters of indicator plants.

Scientific novelty of the research. We showed for the first time that air pollution does not coincide with the official sources of atmospheric pollution given by the Kyiv Bureau of Technical Supervision. We also presented new approach to draw up-to-date, representative, and accurate pollution maps that can be submitted to the representatives of environmental services and other interested parties. Such investigations are of great importance as they can give the opportunity to the government to take real actions on pollutants reducing.

Keywords*: pollution, Air Quality Index, AQI, particulate matter, $PM_{2.5}$, environment, monitoring, city, Kyiv.*

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Introduction. Air pollution is one of the key global environmental problems.

In cities where the air is more polluted, the general morbidity of the population is also greater, according to the World Health Organization [1]. The particulate matter, especially 2.5 micrometers or less in diameter ($PM_{2.5}$ or fine particles), is regarded as one of the most serious components of the urban emissions due to its negative impact on the human health and even mortality [2–5].

In the current situation, the problem is compounded by the positive correlation between the spread of the COVID-19 virus and air pollution. Particulate matter (PM) forms the basis for long-range transmission of the virus. PM also aggravates the symptoms of COVID-19 patients. Such data are presented in many foreign publications in 2020 [6–8]. Although PM concentration, as shown by Daniella and Leonardo Rodriguez-Urrego [9], dropped dramatically during the quarantine period, air quality monitoring remains the most important activity for scientists from around the world, including Ukraine [10].

Different sensors and stations are used by the environmental organizations in Ukraine for the air quality monitoring. Although monitoring stations do not reduce air pollution themselves, they can provide adequate and relevant information about the current state of the air.

Simple and affordable electrochemical sensors for measuring different substances in the air have appeared in the recent years and have quickly become popular. Constantly working servers linked to the sensors set in different locations form the whole monitoring system able to control atmospheric pollution in different points at the same time.

Two monitoring networks constantly provide available for everyone data on the Internet are the most popular in the capital of Ukraine: AQI [11] and

SmartCity [12].

The most popular global monitoring system is an AQI-net that includes over 12000 stations from 100 countries. Air quality monitors collect air pollution data that are converted to the Air Quality Index (AQI). This Index is based on the highest value of five major air pollutants – ground-level ozone (O_3), particle pollution (also known as a particulate matter – $PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_x).

The parameters given in the relative units are based on the comparison with the pollutants MPC (maximum permissible concentration) established by the World Health Organization. The scale includes 6 air pollution levels: 0–50 – good, 51–100 – moderate, 101–150 – unhealthy for sensitive groups, 151–200 – unhealthy, 201–300 – very unhealthy, more than 300 – hazardous.

There are a lot of studies based on the Air Quality Index in different countries.

For example, the sources of air pollution in the Yangtze River Basin [13] and in Romania [14] were classified based on the AQI data. Also, the air quality forecast for different cities of Japan was made by Liu with co-authors [15].

Original monitoring network Carepol has been created to control air pollution in Indonesia [16]. Scientists around the world are developing and offering their own indices for air pollution monitoring [17, 18]. Silva L.T. & Mendes J.F.G. also built a map of urban air pollution with CO_2. Based on this map the municipal service was provided with recommendations for mitigating and improving the air condition in the most "difficult" zones in the city.

Mapping "dry" statistical data on air pollution and its sources enables citizens to better track "clean" and "dirty" places in cities, as well as take measures to control the situation for local authorities [5].

Schmitz O. et al. [19] built quite successful air pollution maps of Belgium and the Netherlands, which show the average annual concentrations of nitrogen, oxides, and dust particles. There is also an eco-map of sources and concentrations of pollutants in China [20].

However, there are still no such maps for Kyiv.

In Kyiv, environmental maps could be used for urban planning and development [21], as well as for strategic detection and control of emission sources [22].

It should be noticed that the current air pollution maps for Kyiv are characterized by the low informational content and insufficient data visualization. Therefore, it is hard to separate sites with differing environmental conditions and the centers of the pollution.

The maps created by the BTS, the former Sanitary and Epidemiological Service (SES, Kyiv) and the CityScale-project [23] are presented in Figures 1–4 as the examples.

The map created by BTS (Fig. 1) includes only qualitative characteristics of some Kyiv districts like “bad” or “good” places. The separate data about pollution sources and concentration of the pollutants are given in the second and the third maps (Fig. 2, 3). It does not seem possible to join these data into the one informative and understandable image. More data about pollution levels have presented in Figure 4, but they are also scattered and don’t give the integral picture of the atmosphere pollution.

Thus, at the moment there are no informative and indicative maps of air pollution in Kyiv. Of cour-

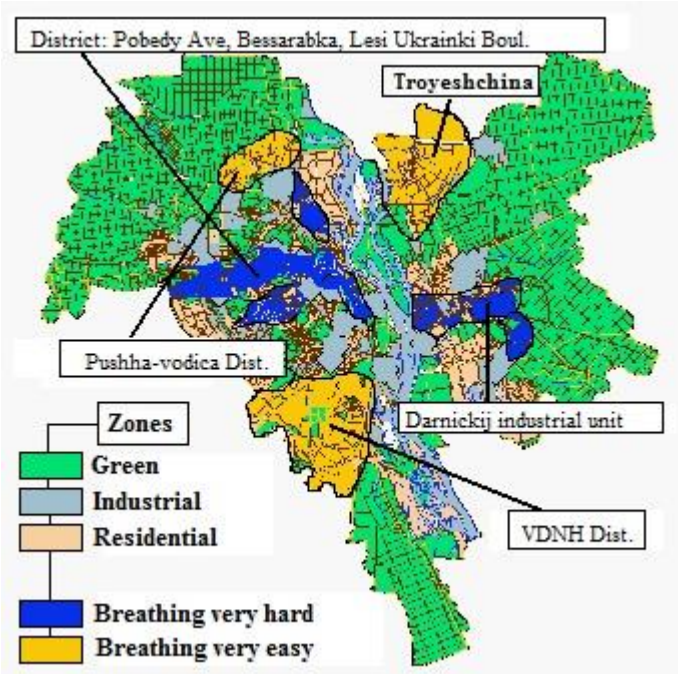


Fig. 1. Environmental map of Kyiv (according to Kyiv Bureau of Technical Supervision)

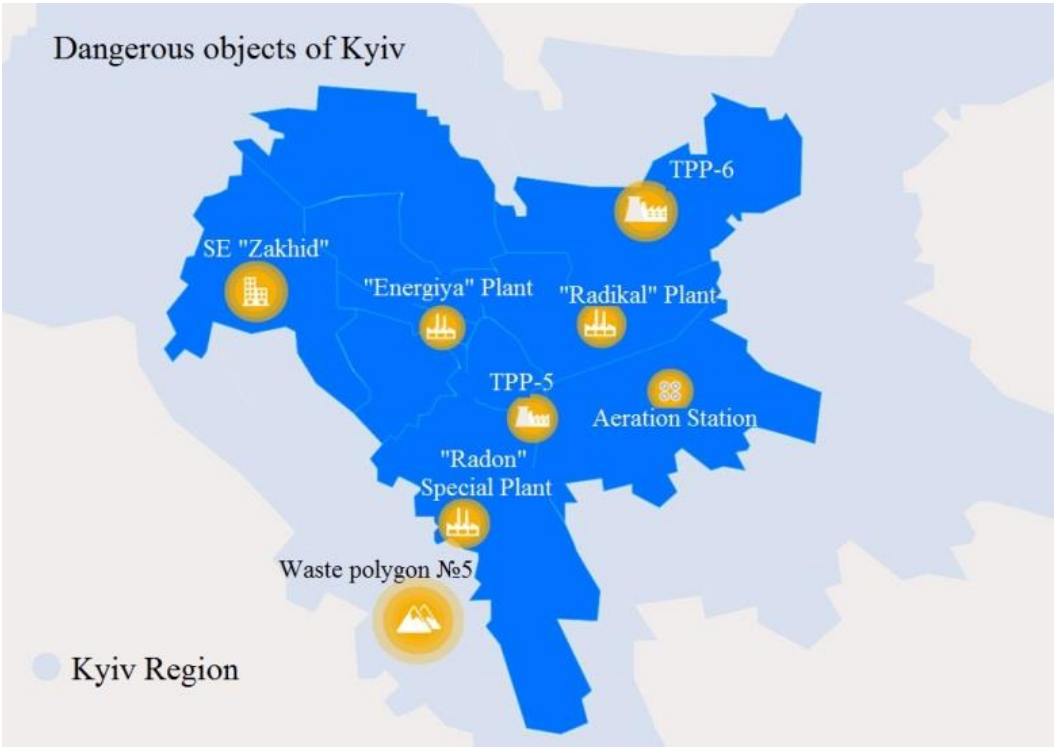


Fig. 2. The main sources of pollution in Kyiv region (published on the website imbf.org)

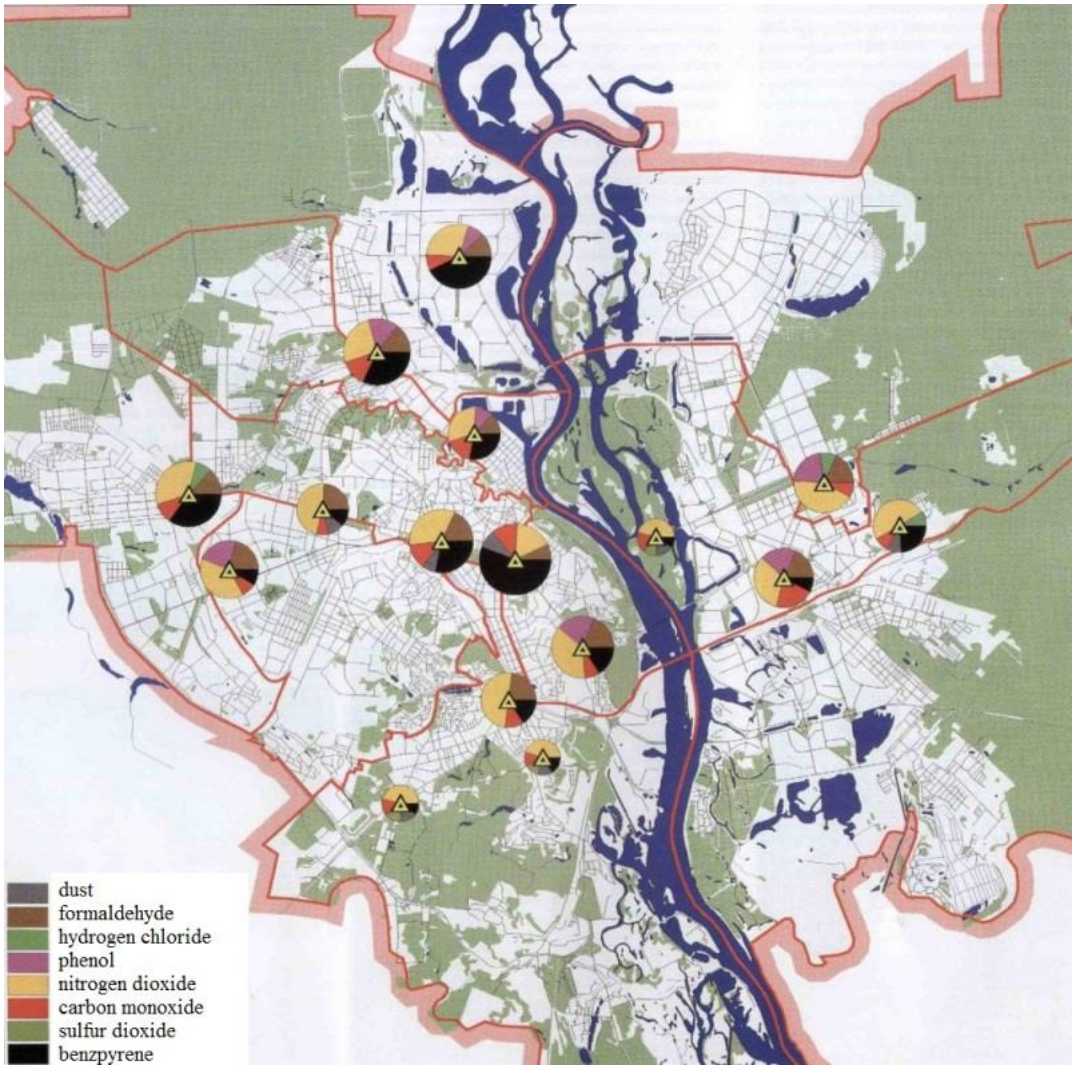


Fig. 3. Air pollution in Kyiv (by BTS)

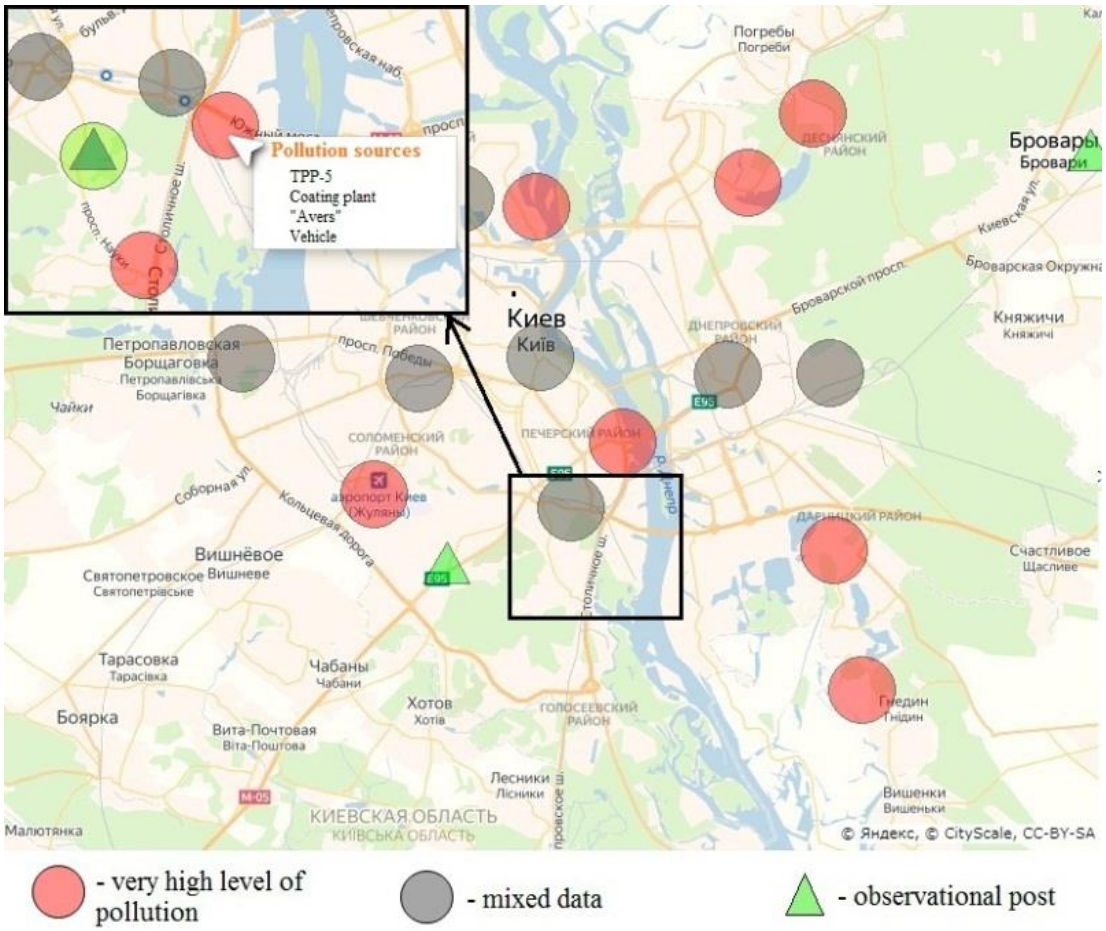


Fig. 4. Pollution sources in Kyiv region (by CityScale)

se, there are many attempts to provide information on pollutants in the form of maps, but all of them do not provide a high-quality and easy-to-interpret picture.

The aim of our study was to develop an approach that allows to create an informative map of Kyiv region pollution based on the data of the AQI's sensors.

To achieve the goal, the following tasks were set:

1) To analyze the data of the AQI network on the main air pollutants in Kyiv for a certain period of time.

2) To analyze morning, afternoon and evening data on dust air pollution (PM).

3) To compare cartographic data with information on the main sources of air pollution in Kyiv.

4) To identify the sources that contribute the most to air pollution in the city.

Materials and methods.

To study the composition of the surface layer of the atmosphere, both instrumental techniques and laboratory analysis are used. In the first case, the concentration of pollutants is analyzed using gas analyzers. For example, gas analyzers MQ135, MQ-7 detects ammonia, benzene, smoke, toxic gases and carbon monoxide in the air [24]. In particular, portable analyzers are available today. With their help everyone can determine the amount of formaldehyde and fine particles in the air, dust, CO, CH_2O, RH and so on.

To analyze the composition of gases in the air in a laboratory, samples are taken in the field, then certain components are isolated using chemical reagents and additional procedures (evaporation, freezing, precipitation) [25].

The main disadvantage of the above methods is the complexity of covering large territories for one researcher, as well as high costs for the laboratory equipment.

The Hydrometeorological Service of Ukraine monitors air pollution in 53 cities of Ukraine with the help of 163 stationary, 2 observation mobile posts and 2 mobile stations. Major pollutants such as dust, nitrogen dioxide, sulfur dioxide, carbon monoxide, formaldehyde, lead and benzopyrene are monitored. Additionally, the presence of heavy metals is monitored: cadmium, iron, manganese, copper, nickel, lead, chromium and zinc, and some other elements [26].

Monitoring at the state level allows to unify data from different cities, as well as take into account weather, climatic conditions, compile statistics for a certain period of time and make a forecast of future changes.

The problem is the difficulty of obtaining all the data of the Hydrometeorological Service, since they are not always available to a wide range of users.

In this situation, AQI is devoid of all disadvanta-

ges. The network includes professional, high-quality sensors, the indicators of which are directly available.

In this study we used the AQI data for Kyiv region as this system gives more parameters than other local monitoring nets (e.g. SmartCity).

Knowing given by the AQI values of the main air pollutants gives us the opportunity to decide what anthropogenic or natural emissions' source makes the greatest contribution into the atmospheric pollution. As it is well documented that:

- transport is the main source of the particulate matter (PM) in the air,
- the high value of NO_x is caused by high temperature technological processes pass in the metallurgical and power plants,
- SO_2 appears as a result of the fossil fuels burning (coal) and
- CO – organic fuels burning (diesel, gasoline);
- O_3 (ozone) level arises in the air due to the electrical devices used by consumers.

We registered all the AQI data during 6 days (from 17.07.2019 to 22.07.2019) at a different time of a day. It was found that morning and evening indices differ substantially, and indices measured at the daytime represented the average value between the first two ones. Thus, we decided to use only morning and evening AQI data.

We chose 15 sensors set on the territory of Kyiv and its surroundings, their full addresses with exact coordinates are given in Table 1.

Data analysis. The data were averaged and then visualized as XYZ contour plots together with longitude and latitude values of the points. The analysis was conducted with OriginPro 8.1 software. The images with a transparency 50% were overlapped on the Google maps. The border areas were smoothed, increments were set as 10% increment.

Results and discussion. Environmental graphs analysis. Air Quality Index analysis. The cumulative AQI values that were received from all sensors for the whole studied period are presented in Figure 5.

It is noteworthy that the center of the most dangerous pollution is in the Svyatoshinskii district and the purest place is in the center of the city on the both sides of the Dnieper river. The results show no clear coincidences with the published maps (see Figures 1–4). Just one source of the pollution marked in Figure 2 – State Enetrprise «Zapad» – occurs in the highly polluted place. However, this object pollutes mainly the soils but not the air as it was the underground storage of high toxic chemicals on its territory during a long period (since 1970s to 2012). At the same time Thermal Power Plant (TPP) number 5, as one of the most powerful sources of the air pollution after vehicle, lies in the relatively clean area.

The center of the polluted area on our graph (see Figure 5) coincides with the building site near the Nyvky district if check on the satellite map.

It should be assumed that the traffic flow on Peremogi Avenue directed towards Europe is the most dangerous source of pollution. In this case we can see the coincidence of the data with the first Figure (see Fig. 1).

Table 1

Addresses and coordinates of the sensors used in the study

№	Address	Longitude	Latitude
1.	Soborna street, 163, Irpin, Kyiv region	30,235559	50,528192
2.	Sim'yi Kulzhenkiv street, 31, Kyiv	30,468016	50,520742
3.	Perova boulevard, 48, Kyiv	30,591417	50,491685
4.	Yurkivska street, 28, Kyiv	30,508242	50,472942
5.	Mykhaila Hrushevskoho street, 30, Kyiv	30,539953	50,444940
6.	DataStory_1, Urlivska street, Kyiv	30,617864	50,409385
7.	Mykhaila Dontsya street, 2, Kyiv	30,432667	50,433793
8.	Vasilya Stusa street, 28A, Kyiv	30,358727	50,460529
9.	Sofiivska Borshchahivka, Soborna street, 114, Kyiv	30,359104	50,408840
10.	Instytut kosmichnykh doslidzhen, Akademika Hlushkova Avenue, Kyiv	30,444866	50,362938
11.	Borispol-1, Kyiv region	30.89656	50.35176
12.	Reheneratorna street, 4, Kyiv	30,623137	50,434631
13.	Pokrovska street, Kyiv-Sviatoshyn district, Kyiv region	30,519283	50,461114
14.	Vadyma Hetmana street, 1v, Solomianskyi district, Kyiv	30,447067	50,452443
15.	MEREZhA-868, Zdolbunivska street, Poznyaky, Darnytskyi district, Kyiv	30,619948	50,416830

Morning and evening $PM_{2.5}$ data analyses. The particulate matter $PM_{2.5}$ concentration in the atmosphere measured in the morning and in the evening during one day (18.07.2019) is given in Figure 6.

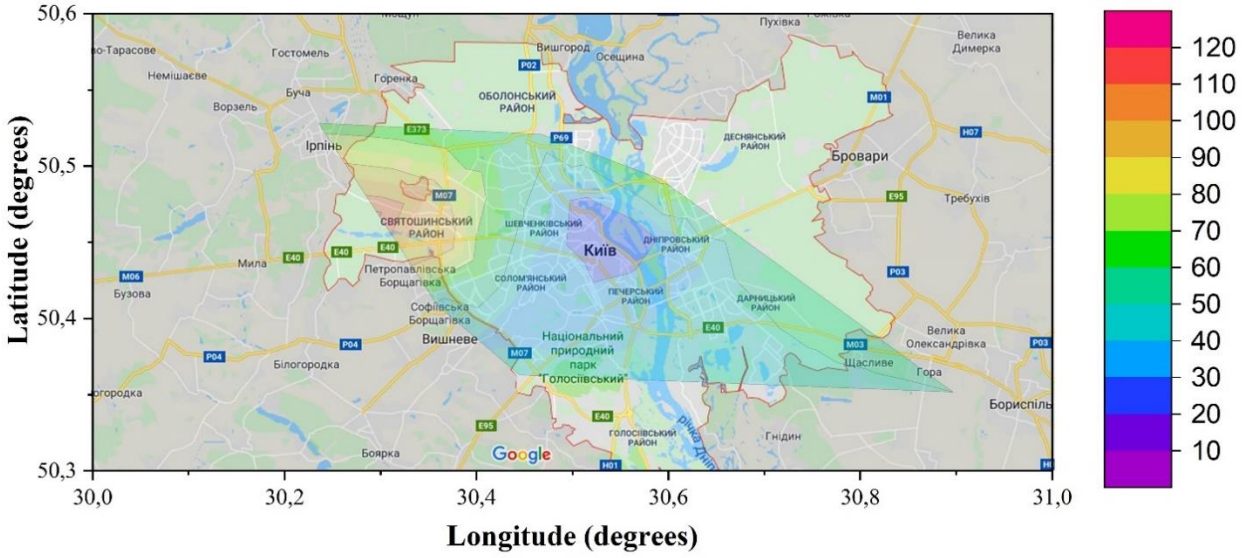
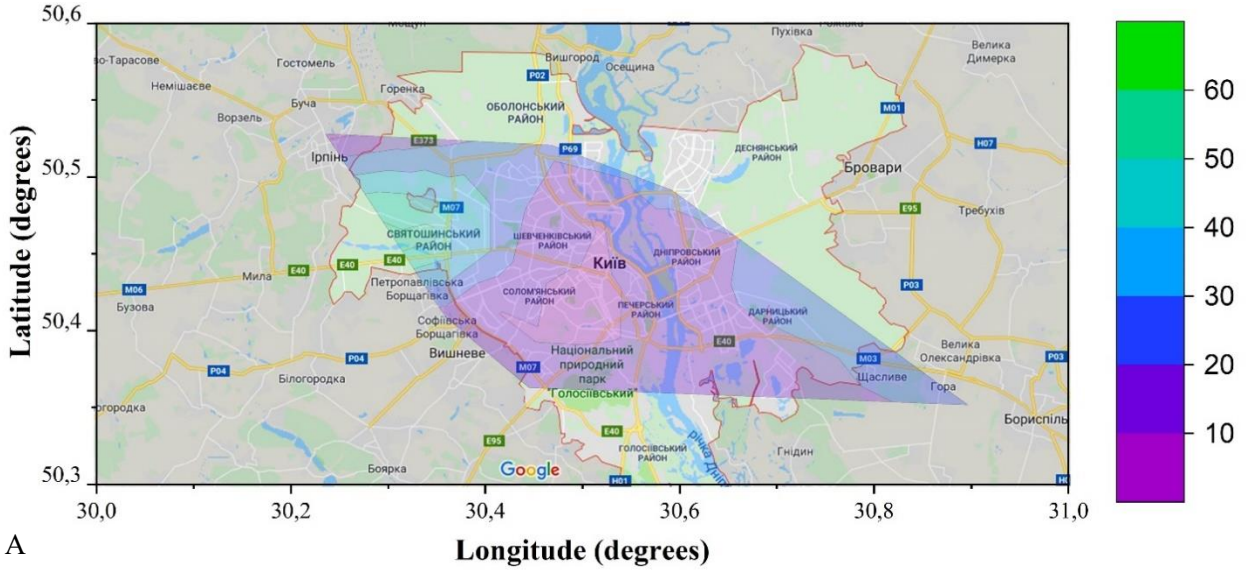
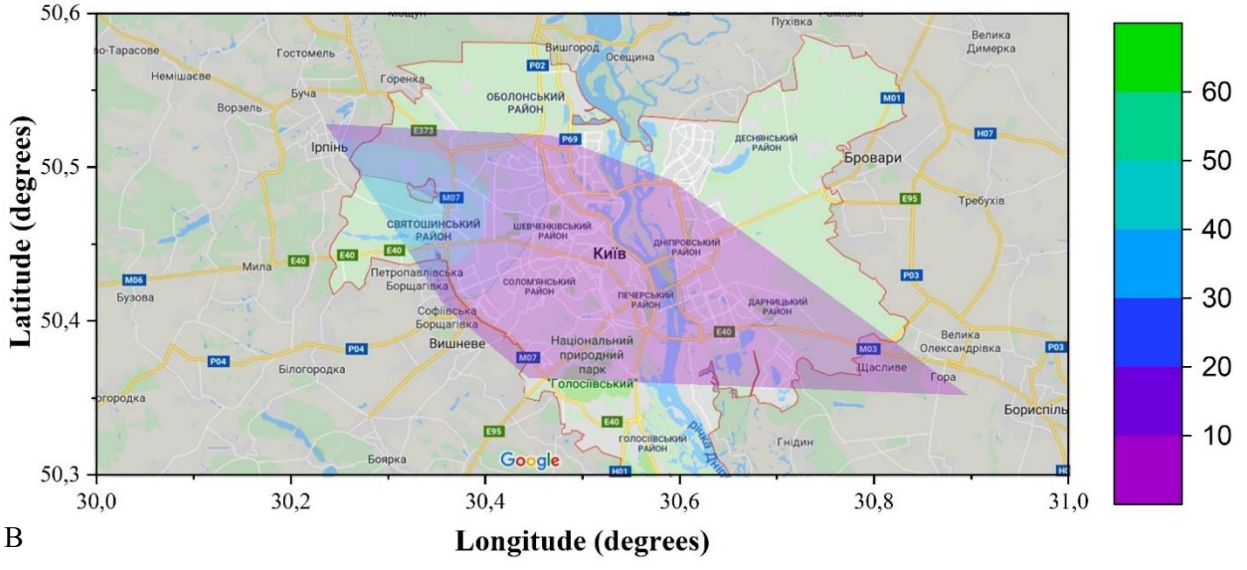


Fig. 5. Morning AQI levels in Kyiv region for the period 17–22.07.2019. Air pollution levels (here and in the figures 6–8): 0–50 – good, 51–100 – moderate, 101–150 – unhealthy for sensitive groups, 151–200 – unhealthy, 201–300 – very unhealthy, more than 300 – hazardous



A



B

Fig. 6. $PM_{2.5}$ concentration in the atmosphere: A – morning data, B – evening data

Morning data about $PM_{2.5}$ concentration are almost the same with the cumulative AQI data except of the clear area in the city center. According to Figure 6 (A) this clear area spreads on the whole central part of the city. In the evening dust disappears in the city suburbs as well.

Particulate matter data analyses (PM_{10} and $PM_{2.5}$). As it was found, the morning data are more informative than the evening ones, we will consider parameters that were taken from the sensors only in the morning hours. Modern laser sensors are able to catch fine (less than 2.5 micrometers) and coarse (less than 10 micrometers) particulate matter in the air. In the next Figure (Fig. 7) there is morning graph for 18.07.2019 showing the distribution of the coarse dust (PM_{10}).

It is clearly seen that the graph with PM_{10} data isn't much representative in regard both to the parameter values and their distribution on the map of the city. Therefore, we will not take them into account in our further analyses.

Comparing the effects of different pollution sources. Transportation is the main source of the air pollution in Kyiv region based on the environmental graphs' analysis. That is why the situation in the city could change greatly from day to day. To check this prediction, we chose the "hardest" day, 22 of July, when AQI in Svyatoshinskii District reached the hazardous level of the air pollution.

Graphs of the air quality index and its components distribution are presented in Figure 8. Primarily it is needed to note the similarity in AQI and $PM_{2.5}$ distribution that means general air quality index in Kyiv is based mainly on the fine dust amount raised by transport.

Other 4 components give the similar picture of the air pollution: clearer northern part of the city compared with the more polluted southern and eastern parts. Obviously, this fact can be explained by the location of three big plants on the south-east of the city – Thermal Power Plants № 5 and № 6, and the incineration plant "Energiya". These objects are the sources of the CO, SO_2, NO_x and O_3 due to the technological processes taking place on their territory, such as burning of organic fuel with high sulfur content at high temperatures and also the distribution of generated electricity [27, 28].

Conclusions. All the initially set tasks were solved during our study:

1) Based on the 6-day monitoring of the indicators of 15 AQI sensors in Kyiv and the Kyiv region, we showed for the first time that air pollution does not coincide with the official sources of atmospheric pollution given by the Bureau of Technical Supervision.

2) We determined that the morning sensor data on the amount of dust in the air is the most informative.

3) It was determined that fine particulate matter ($PM_{2.5}$) contributed more to air pollution, while PM_{10} was not so much informative.

4) It was determined that the main source of air pollution is vehicle.

The main conclusion we can make is that the greatest contribution to the common Air Quality Index of Kyiv city was made by the fine particulate matter ($PM_{2.5}$). Also, vehicular emissions seem to be the main contributor to the $PM_{2.5}$ presence and quantity in the air of the city. The highest level of the fine PM due to our pollution maps was observed on the R30 and E40 highways at the North-West entrance to the city, where massive traffic jam constantly appears in the morning hours.

Using the algorithm experienced in this study

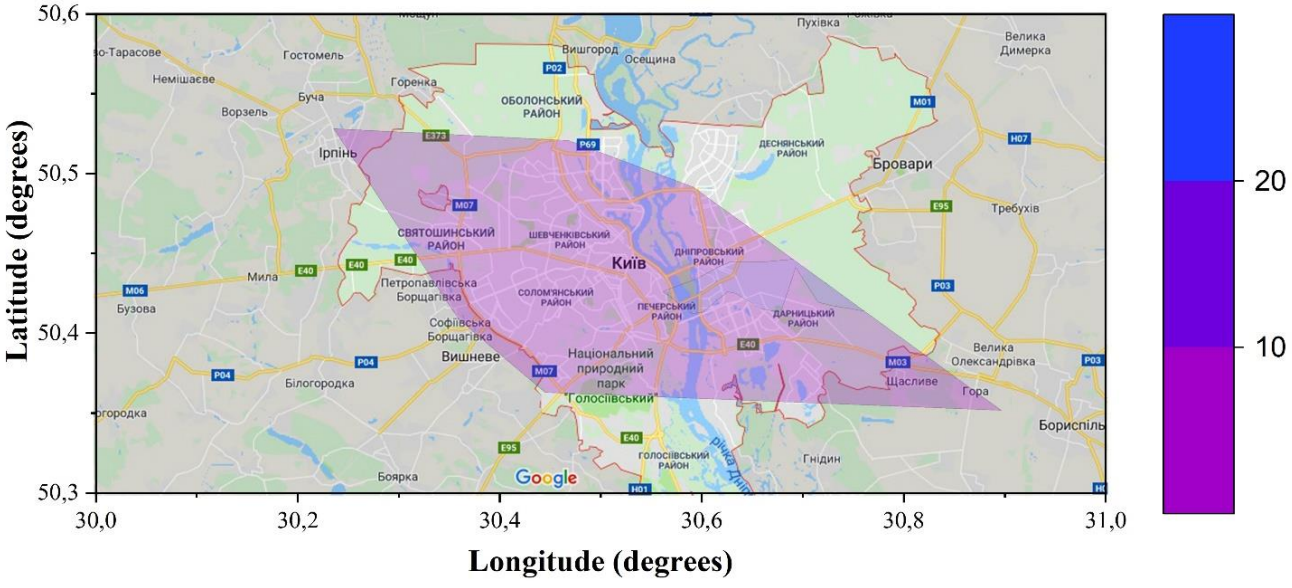


Fig. 7. Morning concentration of the coarse particulate matter

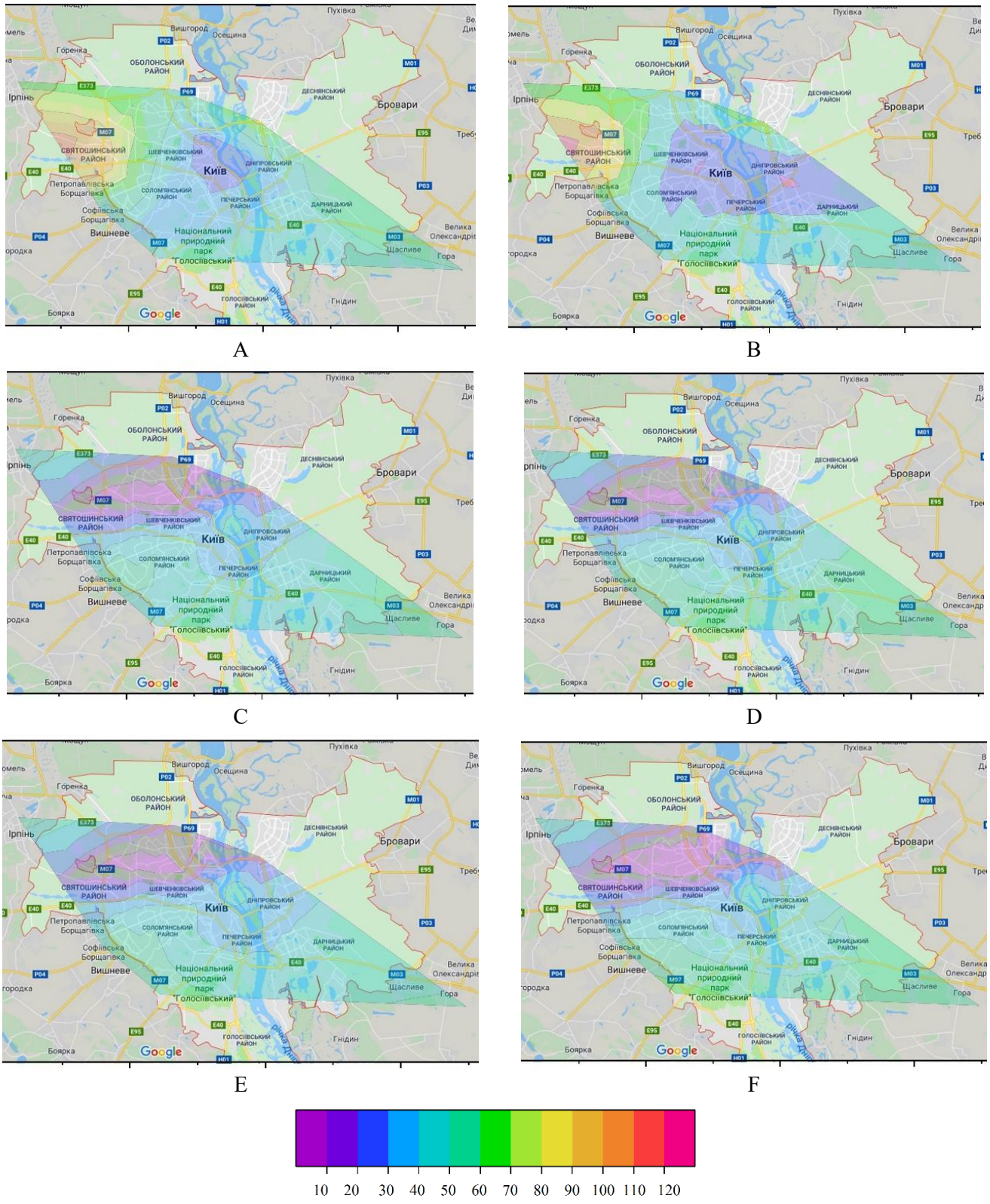


Fig. 8. Comparison of the AQI components distribution in Kyiv region (22.07.2019): A – Air Quality Index, B – $PM_{2.5}$ concentration, C – NO_x concentration, D – SO_2 concentration, E – O_3 concentration, F – CO concentration

and knowing the AQI data for a specific region, it is possible to exclude sources without significant contribution to the whole Air Quality Index, and to highlight the main urban pollutants. The approach has a great advantage among others as allows to draw up-to-date, representative and accurate pollution maps that can be submitted to the representatives of environmental services and other interested parties.

Such investigations are of great importance as they can give the opportunity to the government to take real actions on pollutants reducing.

We want to pay attention that this study is only the first part from the planned set of the research works devoted to the revealing the possibility to use plants, *Plantago lanceolata* in particular, as the air pollution indicators. The object was chosen as it is common ruderal plant species that spreading widely. Also, it was revealed that ribwort plantain is sensitive to air pollutants [29] and climatic factors [30].

It is well-documented that plants can capture PM by their leaves and even be used as an instrument for air mitigating and decontaminating [31, 32]. Besides, plants not only accumulate PM on their leaf surfaces but can be affected by these particles. For this reason, leaves can perform the role of living sensors and their morphological changes can tell us about air contamination with particle matter [33].

We collected plants in all places where the sensors are set and measured parameters of their leaves and stems with spikes. The next step will be to verify our hypothesis and try to find indicative features joined with the PM value in the air.

Bibliography

1. *Ambient air pollution: a global assessment of exposure and burden of disease / World Health Organization. 2016. 121 p. URL: Ambient air pollution: A global assessment of exposure and burden of disease (who.int).*
2. *Zou B., Luo Y., Wan N., Zheng ZH., Sternberg T., Liao Y. Performance comparison of LUR and OK in $PM_{2.5}$ concentration mapping: a multidimensional perspective. Scientific Reports. 2015. №. 5. DOI: https://doi.org/10.1038/srep08698.*
3. *Anenberg S., Schwartz J., Shindell D., Amann M., Faluvegi G., Klimont Z., Janssens-Maenhout G., Pozzoli L., Van Dingenen R., Vignati E., Emberson L., Muller N., West J., Williams M., Demkine V., Hicks W.K., Kuylenstierna J., Raes F., Ramanathan V. Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission control. Environmental Health Perspectives. 2012. Vol. 120, №. 6. P. 831–839.*
4. *Kaiser J. How dirty air hurts the heart. Science. 2015. Vol. 307. P. 1858–1859.*
5. *Wang S.-H., Hung R.-Y., Lin N.-H., Gómez-Losada Á., Pires J., Shimada K., Hatakeyama S., Takami A. Estimation of background PM2.5 concentrations for an air-polluted environment. Atmospheric Research. 2020. Vol. 231. DOI: https://doi.org/10.1016/j.atmosres.2019.104636.*
6. *Karan A., Ali K., Teelucksingh S., Sakhamuri S. The impact of air pollution on the incidence and mortality of COVID-19. Global Health Research and Policy. 2020. Vol. 5, №. 39. DOI: https://doi.org/10.1186/s41256-020-00167-y.*
7. *Comunian S., Dongo D., Milani Ch., Palestin P. Air pollution and COVID-19: the role of particulate matter in the spread and increase of COVID-19's morbidity and mortality. International Journal of Environmental Research and Public Health. 2020. Vol. 17, №. 12. DOI: https://dx.doi.org/10.3390%2Fijerph17124487.*
8. *Zoran M.A., Savastru R.S., Savastru D.M., Tautan M.N. Assessing the relationship between surface levels of PM2.5 and PM10 particulate matter impact on COVID-19 in Milan, Italy. Science of the Total Environment. 2020. №. 738. DOI: https://doi.org/10.1016/j.scitotenv.2020.139825.*
9. *Rodriguez-Urrego D., Rodriguez-Urrego L. Air quality during the COVID-19: PM2.5 analysis in the 50 most polluted capital cities in the world. Environmental Pollution. 2020. Vol. 266, №. 1. DOI: https://doi.org/10.1016/j.envpol.2020.115042.*
10. *World Bank. Ukraine Country Environmental Analysis. World Bank, Washington, DC, 2016. URL: https://openknowledge.worldbank.org/handle/10986/24971.*
11. *World's Air Pollution: Real-time Air Quality Index. 2020. URL: https://waqi.info/.*
12. *Kyiv Smart Environment / Kyiv Smart City. 2020. URL: https://air.kyivsmartcity.com/.*
13. *Song Yu, Liu B., Chen X., Liu J. Atmospheric pollution mapping of the Yangtze River Basin: an AQI-based weighted co-word analysis. International Journal of Environmental Research and Public Health. 2020. Vol. 17, №. 817. DOI: https://doi.org/10.3390/ijerph17030817.*
14. *Popescu F., Ionel I., Lontis N., Calin L., Dungan I.L. Air quality monitoring in an urban agglomeration. Romanian Journal of Physics. 2011. Vol. 56, №. 3–4. P. 495 – 506.*
15. *Liu B.-Ch., Binaykia A., Chang P.-Ch., Tiwari M.K., Tsao Ch.-Ch. Urban air quality forecasting based on multi-dimensional collaborative Support Vector Regression (SVR): A case study of Beijing-Tianjin-Shijiazhuang. PLoS One. 2017. Vol. 12, №. 7. DOI: https://doi.org/10.1371/journal.pone.0179763.*
16. *Agus M., Iqbal S.S. Urban air pollution monitoring system for mapping areas based on pollutant level. Materials Science and Engineering: IOP Conference Series. 2019. Vol. 662, №. 4. DOI: https://doi.org/10.1088/1757-899X/662/4/042010.*
17. *Murena F. Measuring air quality over large urban areas: development and application of an air pollution index at the urban area of Naples. Atmospheric Environment. 2004. Vol. 38. P. 6195–6202. DOI: https://doi.org/10.1016/j.atmosenv.2004.07.023.*
18. *Silva L.T., Mendes J. F. G. A new Air Quality Index for cities. Farhad Nejadkoorki (Eds.), Advanced Air Pollution. 2011. DOI: https://doi.org/10.5772/16701.*
19. *Schmitz O., Beelen R., Strak M., Hoek G., Soenario I., Brunekreef B., Vaartjes I., Dijst M.J., Grobbee D.E., Karssenberg D. Data Descriptor: High resolution annual average air pollution concentration maps for the Netherlands. Scientific Data. 2019. Vol. 6. DOI: https://doi.org/10.1038/sdata.2019.35.*

20. Rohde R., Muller R. Air pollution in China: mapping of concentrations and sources. PLoS ONE. 2015. Vol. 10, №. 8. DOI: https://doi.org/10.1371/journal.pone.0135749.
21. Bureau of Technical Supervision / Technical supervision of construction. Management of construction projects. Engineer Technical Supervision. 2020. URL: www.btn.kiev.ua/en/.
22. Ministry of Ecology and Natural Resources of Ukraine. 2020. URL: https://menr.gov.ua/en/.
23. CityScale. Pollution Sources. 2020. URL: www.cityscale.com.ua.
24. John B.J., Harish C., Lawrence C.C., Krishnakumar S., Divakaran S., Premkumar J., Kanmani P.G., Sabarivani A., Jagadeesan A.K. Monitoring indoor air quality using smart integrated gas sensor module (IGSM) for improving health in COPD patients. Environmental Science and Pollution Research. 2023. №. 30. P. 28889–28902.
25. Katulski R.J., Namieśnik J., Sadowski J., Stefański J., Wardencki W. Monitoring of gaseous air pollution. The impact of air pollution on health, economy, environment and agricultural sources / Edited by Khallaf M. Fayoum University, Egypt, 2011. DOI: https://doi.org/10.5772/20771
26. Averin G. European neighborhood and partnership instrument – shared environmental information system / Country report of Ukraine, Zoï Environment Network, Geneva, Switzerland, 2012.
27. Savenets M., Dvoretska I., Nadtochii L. Current state of atmospheric air pollution in Ukraine based on sentinel-5p satellite data. Visnyk of Karazin Kharkiv National University, series "Geology. Geography. Ecology". 2019. Vol. 51. P. 221–233. DOI: https://doi.org/10.26565/2410-7360-2019-51-16.
28. Pribylova B.N. Assessment of anthropogenic impact on the geological environment and features of the accumulation of pollutants in the zone of the Zmyiv thermal power-station (Kharkiv region). Visnyk of V.N. Karazin Kharkiv National University, series "Geology. Geography. Ecology". 2013. Vol. 39, №. 1084. P. 237–243.
29. Skrynetska I., Karcz J., Barczyk G., Kandziora-Ciupa M., Ciepał R., Nadgórska-Socha A. Using Plantago major and Plantago lanceolata in environmental pollution research in an urban area of Southern Poland. Environmental Science and Pollution Research. 2019. DOI: https://doi.org/10.1007/s11356-019-05535-x.
30. Prokhorova S., Netsvetov M. Morphological and phenological shifts in the Plantago lanceolata L. species as linked to climate change over the past 100 years. Hacquetia. 2020. Vol. 19, №. 2. P. 293–305. DOI: https://ojs.zrc-sazu.si/hacquetia/article/view/7662/7862.
31. Bharti S.K., Trivedi A., Kumar N. Air pollution tolerance index of plants growing near an industrial site. Urban Climate. 2017. DOI: http://dx.d0i.0rg/l0.1016/j.uclim.2017.10.007.
32. Viecco M., Vera S., Jorquera H., Bustamante W., Gironás J., Dobbs C., Leiva E. Potential of particle matter dry deposition on green roofs and living walls vegetation for mitigating urban atmospheric pollution in semiarid climates. Sustainability. 2018. Vol. 10. DOI: https://doi.org/10.3390/su10072431.
33. Chen X., Zhou Zh., Teng M., Wang P., Zhou L. Accumulation of three different sizes of particulate matter on plant leaf surfaces: effect on leaf traits. Archives of Biological Sciences. 2015. Vol. 67, №. 4. P. 1257–1267. DOI: https://doi.org/10.2298/ABS150325102C.

References

1. Ambient air pollution: a global assessment of exposure and burden of disease. (2016). World Health Organization. – 121. (available on the https://www.who.int/phe/publications/air-pollution-global-assessment/en/).
2. Zou, B., Luo, Y., Wan, N., Zheng, ZH., Sternberg, T., Liao, Y. (2015). Performance comparison of LUR and OK in PM2.5 concentration mapping: a multidimensional perspective. Scientific Reports, 5 (8698). https://doi.org/10.1038/srep08698.
3. Anenberg, S., Schwartz, J., Shindell, D., Amann, M., Faluvegi, G., Klimont, Z., Janssens-Maenhout, G., Pozzoli, L., Van Dingenen, R., Vignati, E., Emberson, L, Muller, N., West, J., Williams, M., Demkine, V., Hicks, W.K., Kuylenstierna, J., Raes, F., Ramanathan, V. (2012). Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission control. Environmental Health Perspectives, 120.
4. Kaiser, J. (2015). How dirty air hurts the heart. Science, 307, 1858-1859.
5. Wang, S.-H., Hung, R.-Y., Lin, N.-H., Gómez-Losada, Á., Pires, J., Shimada, K., Hatakeyama, S., Takami, A. (2020). Estimation of background PM2.5 concentrations for an air-polluted environment. Atmospheric Research, 231. https://doi.org/10.1016/j.atmosres.2019.104636.
6. Karan, A., Ali, K., Teelucksingh, S., Sakhamuri S. (2020). The impact of air pollution on the incidence and mortality of COVID-19. Global Health Research and Policy, 5(39). https://doi.org/10.1186/s41256-020-00167-y.
7. Comunian, S., Dongo, D., Milani, Ch., Palestin, P. (2020). Air pollution and COVID-19: the role of particulate matter in the spread and increase of COVID-19's morbidity and mortality. International Journal of Environmental Research and Public Health, 17(12): 4487. https://dx.doi.org/10.3390%2Fijerph17124487.
8. Zoran, M.A., Savastru, R.S., Savastru, D.M., Tautan, M.N. (2020). Assessing the relationship between surface levels of PM2.5 and PM10 particulate matter impact on COVID-19 in Milan, Italy. Science of the Total Environment, 738. https://doi.org/10.1016/j.scitotenv.2020.139825.
9. Rodriguez-Urrego, D., Rodriguez-Urrego, L. (2020). Air quality during the COVID-19: PM2.5 analysis in the 50 most polluted capital cities in the world. Environmental Pollution, 266(1):115042. https://doi.org/10.1016/j.envpol.2020.115042.
10. World Bank. Ukraine Country Environmental Analysis. (2016). World Bank, Washington, DC. Retrieved from: https://openknowledge.worldbank.org/handle/10986/24971.

11. World's Air Pollution: Real-time Air Quality Index (2020). Retrieved from https://waqi.info/.
12. Kyiv Smart Environment. Kyiv Smart City (2020). Retrieved from https://air.kyivsmartcity.com/.
13. Song, Yu, Liu, B., Chen, X., Liu, J. (2020). Atmospheric pollution mapping of the Yangtze River Basin: an AQI-based weighted co-word analysis. International Journal of Environmental Research and Public Health, 17 (817). https://doi.org/10.3390/ijerph17030817.
14. Popescu, F., Ionel, I., Lontis, N., Calin, L., Dungan, I.L. (2011). Air quality monitoring in an urban agglomeration. Romanian Journal of Physics, 56 (3–4), 495-506.
15. Liu, B.-Ch., Binaykia, A., Chang, P.-Ch., Tiwari, M.K., Tsao, Ch.-Ch. (2017). Urban air quality forecasting based on multi-dimensional collaborative Support Vector Regression (SVR): A case study of Beijing-Tianjin-Shijiazhuang. PLoS One, 12 (7): e0179763. https://doi.org/10.1371/journal.pone.0179763.
16. Agus, M. & Iqbal, S.S. (2019). Urban air pollution monitoring system for mapping areas based on pollutant level. IOP Conference Series: Materials Science and Engineering, 662 (4). https://doi.org/10.1088/1757-899X/662/4/042010.
17. Murena, F. (2004). Measuring air quality over large urban areas: development and application of an air pollution index at the urban area of Naples. Atmospheric Environment, 38, 6195–6202. https://doi.org/10.1016/j.atmosenv.2004.07.023.
18. Silva, L.T., Mendes, J. F. G. (2011). A new Air Quality Index for cities. In: Farhad Nejadkoorki (Eds.), Advanced Air Pollution. https://doi.org/10.5772/16701.
19. Schmitz, O., Beelen, R., Strak, M., Hoek, G., Soenario, I., Brunekreef, B., Vaartjes, I., Dijst, M.J., Grobbee, D.E., Karssenberg, D. (2019). Data Descriptor: High resolution annual average air pollution concentration maps for the Netherlands. Scientific Data, 6:190035. https://doi.org/10.1038/sdata.2019.35.
20. Rohde, R., & Muller, R. (2015). Air pollution in China: mapping of concentrations and sources. PLoS ONE, 10(8): e0135749. https://doi.org/10.1371/journal.pone.0135749.
21. Bureau of Technical Supervision. Technical supervision of construction. Management of construction projects. Engineer Technical Supervision. (2020). Retrieved from www.btn.kiev.ua/en/.
22. Ministry of Ecology and Natural Resources of Ukraine. (2020). Retrieved from https://menr.gov.ua/en/.
23. CityScale. Pollution Sources. (2020). Retrieved from www.cityscale.com.ua.
24. John B.J., Harish C., Lawrence C.C., Krishnakumar S., Divakaran S., Premkumar J., Kanmani P.G., Sabarivani A., Jagadeesan A.K. Monitoring indoor air quality using smart integrated gas sensor module (IGSM) for improving health in COPD patients. Environmental Science and Pollution Research. 2023. №. 30. P. 28889–28902.
25. Katulski R.J., Namieśnik J., Sadowski J., Stefański J., Wardencki W. Monitoring of gaseous air pollution. The impact of air pollution on health, economy, environment and agricultural sources. Edited by Khallaf M. Fayoum University, Egypt, 2011. DOI: https://doi.org/10.5772/20771
26. Averin, G. (2012). European Neighbourhood and Partnership Instrument – Shared Environmental Information System. Country Report of Ukraine, Zoï Environment Network, Geneva, Switzerland.
27. Savenets, M., Dvoretska, I., Nadtochii, L. (2019). Current state of atmospheric air pollution in Ukraine based on sentinel-5p satellite data. Visnyk of V.N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", 51, 221-233. https://doi.org/10.26565/2410-7360-2019-51-16.
28. Прибылова, В.Н. (2013). Assessment of anthropogenic impact on the geological environment and features of the accumulation of pollutants in the zone of the Zmyiv thermal power-station (Kharkiv region). Visnyk of V.N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", 39 (1084), 237-243.
29. Skrynetska, I., Karcz, J., Barczyk, G., Kandziora-Ciupa, M., Ciepał, R., Nadgórska-Socha, A. (2019). Using Plantago major and Plantago lanceolata in environmental pollution research in an urban area of Southern Poland. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-019-05535-x.
30. Prokhorova, S., Netsvetov, M. (2020). Morphological and phenological shifts in the Plantago lanceolata L. species as linked to climate change over the past 100 years. Hacquetia, 19 (2), 293-305. https://ojs.zrc-sazu.si/hacquetia/article/view/7662/7862.
31. Bharti, S.K., Trivedi, A., Kumar, N. (2017). Air pollution tolerance index of plants growing near an industrial site. Urban Climate. http://dx.d0i.0rg/l0.1016/j.uclim.2017.10.007.
32. Viecco, M., Vera, S., Jorquera, H., Bustamante, W., Gironás, J., Dobbs, C., Leiva, E. (2018). Potential of particle matter dry deposition on green roofs and living walls vegetation for mitigating urban atmospheric pollution in semi-arid climates. Sustainability, 10 (2431). https://doi.org/10.3390/su10072431.
33. Chen, X., Zhou, Zh., Teng, M., Wang, P., Zhou, L. (2015). Accumulation of three different sizes of particulate matter on plant leaf surfaces: effect on leaf traits. Archives of Biological Sciences. 67(4), 1257-1267. https://doi.org/10.2298/ABS150325102C.

Підхід до використання компонентів індексу якості повітря AQI для визначення джерел забруднення повітря в місті

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Те, що повітря, яким ми дихаємо, забруднене – не новина. Джерел забруднення дуже багато, особливо, в великих містах. Для контроля забруднюючих речовин у повітрі встановлюють різноманітні датчики. Одна із глобальних систем реєстрації концентрації полютантів у міському повітрі – AQI. І хоча самі датчики не здатні зменшувати забруднення у повітрі, на базі тих даних, що вони надають, можна створювати показові карти забруднення міст. Таке картування міських територій дасть змогу вповноваженим органам розробляти та впроваджувати плани з покращення найнебезпечніших зон, як це вже робиться в інших країнах. Мета даної роботи – аналіз індексу якості повітря у Києві, визначення головного джерела атмосферного забруднення та побудова наочних екологічних карт. Ми проаналізували 5 головних показників, на яких базується індекс якості повітря, за визначений період у м. Київ та його околицях. Використовували дані 15 датчиків всесвітньої мережі AQI. Завдяки тому, що відомі точні координати кожного датчика та результати їхніх вимірювань, вдалось побудувати карти забруднення повітря, використовуючи програмне забезпечення OriginPro 8.1 та зображення з Google maps. Визначено, що найбільший внесок до індексу якості повітря дає суспензія дрібного пилу. Основним джерелом $PM_{2.5}$ в місті є транспорт. На нашій карті наочно показано, що ділянка з найбільшим значенням AQI співпадає з великою транспортною розв'язкою на північно-західній околиці міста. Таким чином, атмосферне забруднення у Києві визначається переважно кількістю дрібних часток пилу у повітрі. Ми вперше показали, що забруднення атмосфери не збігається з офіційними джерелами забруднення атмосфери, наданими Київським бюро технічного нагляду. Ми також представили новий підхід до складання актуальних, репрезентативних і точних карт забруднення, які можна надати представникам екологічних служб та іншим зацікавленим сторонам. Такі дослідження мають велике значення, оскільки вони можуть дати можливість уряду вжити реальних заходів щодо зменшення забруднюючих речовин.Подальше дослідження буде спрямовано на виявлення зв'язку кількості $PM_{2.5}$ у повітрі та морфологічних параметрів рослин-індикаторів.

Ключові слова*: забруднення, індекс якості повітря, AQI, тверді частки, $PM_{2.5}$, навколишнє середовище, моніторинг, місто, Київ.*

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