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## DEVELOPMENT OF ATMOSPHERIC AIR MONITORING SYSTEM IN DROHOBYCH

**Abstract.** The problem of air pollution is important issue for many cities in Ukraine. Improving the air quality starts from the constant control for the air pollution. Cities in European Union have the developed monitoring system connected to the Internet. In Ukraine the similar measures are implemented within the state program of creating regional monitoring systems. An air monitoring system for the city of Drohobych is proposed in the article. It is shown that the city in the past had significant industrial potential, has a developed transport infrastructure. The main sources of air pollution in the city have been identified. The proposed monitoring system should include 3-4 automated observation posts, which in real time will reflect the state of the air in key points of the city. The created system will allow monitoring the state of atmospheric air in the city, providing citizens and relevant services with up-to-date information on the state of the environment.

**Key words:** Drohobych, monitoring, atmospheric air, automated observation posts.

The problem of air pollution in Ukrainian cities continues to be relevant. In a number of cities, it is associated with the activities of enterprises operating there, as well as with the growing traffic load. The main industries creating the load are metallurgy, energy, production of building materials, chemical industry. For cities where there is no powerful industrial production, the main polluter is road transport. Although modern vehicles emit less and less toxic substances into the air, the number of cars meeting modern environmental safety requirements on Ukrainian roads is insignificant [5].

It is the increase in the level of gassiness in large cities of Ukraine and the negative phenomena provoked by it, such as smog, that have caused the need to control and monitor the state of the atmospheric air. In cities with a population of millions and regional centers began to create programs to control and monitor the state of the air. Today, a network of observation points that allow monitoring the state of atmospheric air in real time has been created in such large centers as Kyiv, Lviv, Odessa, Dnipro. Thus, a network of more than 20 posts operates in Lviv, and more than 40 posts operate in Kyiv [8; 9].

Atmospheric air monitoring systems are beginning to be introduced in district centers as well. As an example, we can cite several cities in the Kyiv region, where posts of observations of the state of atmospheric air were established. Similar posts are established in the district centers of Lviv region. However, 1 post per city may not always adequately reflect the situation with air pollution. For example, in a city with a population of about 70,000 inhabitants, which is Przemyśl in Poland, there are at least three observation posts [2].

In the countries of the European Union the approach on use of posts of the automated control over an air condition measuring a certain defined list of indicators is realized today. In Ukraine, in addition to standard indicators, the monitoring system may also provide for the measurement of a number of specific indicators related to the activities of the relevant industries [17; 18].

In general, the functioning system of monitoring the state of atmospheric air in cities is just beginning to develop. According to the resolution of the Cabinet of Ministers of Ukraine and the

order of the Ministry of Environmental Protection and Natural Resources, local governments can develop programs to monitor the state of the air. The program indicates data on the object of monitoring, the body controlling air quality, data on air pollution in the village. The following describes the current and planned air quality control system. A number of Ukrainian cities have developed and are implementing similar programs [13]. The most acceptable form of control is the establishment of a number of automated posts in key points of the settlement. Posts are also connected to the Internet and information systems of local governments. This system allows you to obtain data and respond quickly to changes in the environmental situation in the city [5].

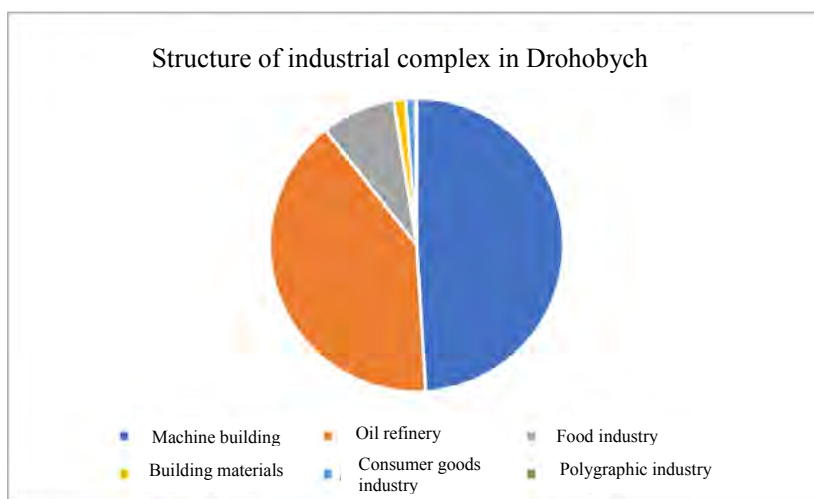
## MATERIALS AND METHODS OF THE RESEARCH

Drohobych is a city of regional significance in the Lviv region, a district center. The city of Stebnyk is also subordinated to the city territorial community. The city is located on the border of the Transnistrian plain and the Carpathian foothills, on the river Tysmenytsia (bass. Dniester), 86 km from the regional center. The area of the city is 44.5 km<sup>2</sup>. The population as of 2021 was 74,610 people.

The city of Drohobych is one of the powerful industrial centers of Lviv region. In Soviet times, the city had powerful enterprises – a refinery, a bit factory, light and food industries. Today, a number of enterprises are closing or reducing production [11].

The city's industrial infrastructure includes the oil refining and petrochemical industries, mechanical engineering and metalworking, light and food industries, woodworking, construction and printing companies. The main types of industrial products are gasoline, diesel fuel, lubricants, drill bits, oil and mining equipment, cleaning and insulation machines, truck cranes, light and food industry products, table salt, mineral potash fertilizers. The main enterprises of the city are "Galychyna Oil Refinery", "Drohobych Chisel Plant", "Drohobych Truck Crane Plant", "Drohobych Machine-Building Plant", saltworks [1].

The structure of the industrial potential of the city is presented in Fig. 1.



**Fig. 1. Structure of the industrial potential of Drohobych**

The multidisciplinary industrial complex includes 31 industrial enterprises that are on a constant balance (excluding small enterprises), which produce a wide range of industrial products. The largest enterprises are presented in table 1.

**Table 1. Information about industrial enterprises of Drohobych (as of 2020)**

<b>Enterprise name</b>	<b>Legal Address</b>	<b>List of main products</b>
PJSC "Stebnytske HCP "Polym mineral"	Stebnyk, Drohobyt'ska Str., 127	stopped for reconstruction (produced mineral fertilizers)
SE "Drohobych Salt Plant"	Soliany Stavok Str., 27	salt production
Drohobych Meat Processing Plant LLC	Truskavetska Str., 114	Production of meat and sausages
PJSC "Drohobych Bakery"	Repina Str., 8	production of bakery and confectionery products
SE UTG Ukraine (DENMARK)	Sambirska Str., 85	sewing of garment (knitted) items
Dekarest LLC	Sambirska Str., 85	sewing of garments for decoration
MPP MAK	B. Khmelnytsky Str., 33	sewing of garments
Ukkan LLC	P. Orlyk Str., 26	production of blanks for parquet, parquet and lumber
Sapsan LLC	Stebnyk, V. Velikoho Str., 12-A	production of joinery (interior doors)
PE "Kolo"	Boryslavska Str., 8	issue of books, magazines and other printing products
OJSC "NPK-Galichina"	Boryslavska Str., 82	oil refining, production of gasoline, diesel fuel and fuel oil
OJSC "Drohobych Paint"	Haydamatska Str., 28	production of paints and varnishes
Subsidiary company "Pharmatrade"	Sambirska Str., 85	production of injectable solutions
OJSC "Drohobych Plant Management of Building Materials"	Truskavetska Str., 73	brick production
PJSC "Drohobych Plant of Reinforced Concrete Products"	Fabrychna Str., 61	production of reinforced concrete products
Bystrytsia-Keramik LLC	Zarichna Str., 34	electrical insulating ceramics, insulators
Universal Drilling Equipment LLC	Turasha Str., 20	production of chisels
Drohobych Penal Colony No. 40	Truskavetska Str., 77	fastenings for mines, forged products, sawing of wood, etc.
PJSC "Drohobych Truck Crane Plant?"	Haydamatska Str., 22	produced truck cranes, and the work on the rehabilitation of the enterprise is currently performed

**Table 1 (continuance)**

OJSC “Drohobych Machine-Building Plant”	Boryslavska Str., 51/1	production of drilling equipment and tools
ISM Joint Venture	Turasha Str., 20	production of cone tools
Furniture enterprise “Karpaty” UTOG	Industrialna Str., 1	production of joinery and furniture, including office

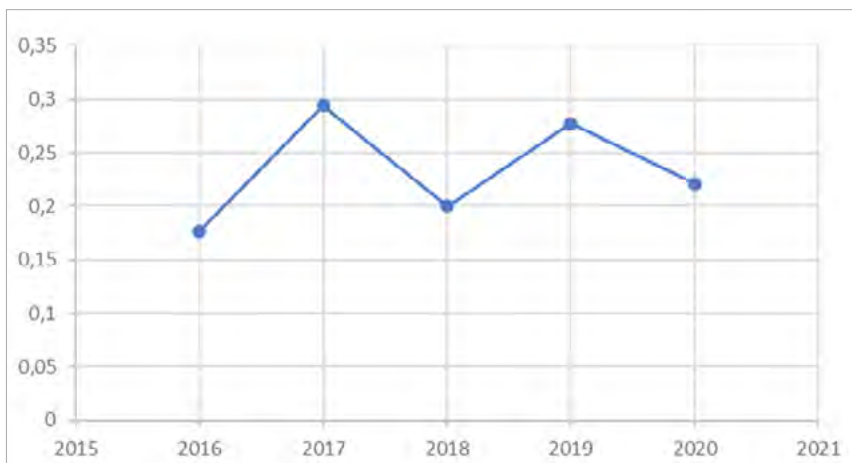
The transport complex of the city is represented mainly by rail and road transport. Drohobych railway station is located in the eastern part of the city. Previously, there was a so-called “Small Station” on Boryslavska Street, now it is located on the territory of the refinery. Drohobych's public transport consists of buses. In Soviet times, buses operated in the city, but in the 1990s they were replaced by an increase in the number of minibuses [].

In 2016, the implementation of the project “Drohobych – Smart City” began in Drohobych, on the initiative of Mayor Taras Kuchma (project leaders’ advisor to the mayor Stanislav Haider, director of KU “Drohobych City Institute” Volodymyr Kondziolka). In one year, the city has launched more than twenty electronic services, namely: through the Internet, city residents order administrative services, through electronic maps report problems in the housing and communal sector, illegal advertising, illegal trade, etc. The city has an electronic record for an appointment with a doctor, deputy, official, city administration. Drohobych is intensively pursuing a policy of openness, so electronic analytical systems for the city budget, e-procurement, voting in the parliamentary corps and much more work for the city's residents. There are ten free Wi-Fi zones in the city. In the central part of the city there are electronic touch kiosks where city residents can learn about the latest events and news. Drohobych has its own mobile application on Ios and Android platforms where emergency situations are also reported. The city has launched an open portal of the city where you can get free access to all important information about the life of the city. Drohobych is one of the few cities in Ukraine demonstrating online sessions, executive committees, meetings and events using its own capabilities. Drohobych can also be watched online using the city's webcams [15].

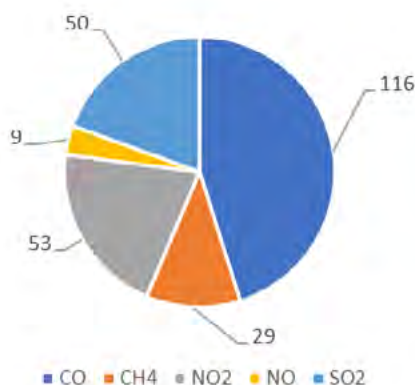
Already in 2017, the city of Drohobych was ranked in the top ten most transparent cities in Ukraine by Transparency International Ukraine. In September 2017, the city joined the International Open Data Charter (G8 project). In November 2017, the city of Drohobych received the award and first place as the best practice of local government (thanks to the project “Drohobych – Smart City”) in the ranking of the Ministry of Regional Development, Construction and Housing of Ukraine. The largest mass media of Ukraine write about the city as an example. Project initiators Stanislav Haider and Volodymyr Kondziolka continue to develop the city's ecosystem, as well as teach other communities how to become “smart”.

Drohobych ranks second in the region in terms of the level of pollution from stationary sources. Located on its territory PJSC NPK “Galychyna” is one of the ten air pollutants in Lviv region. However, according to the environmental services of the region, the city is not among the most polluted in the region. Here the championship is occupied by Lviv, Chervonohrad, Dobrotvir and Stryy. The main pollutants recorded in the city air are carbon, nitrogen and sulfur oxides. The structure of emissions in the city as of 2020 is presented in Fig. 3.

The city is gradually implementing a system of air control. Thus, in 2019 in Drohobych established the first post of control of atmospheric air at the address of st. Konovaltsia, 7. However, air quality data have not been updated for several months. Current data cannot be obtained. However, even a single post is not able to give an adequate picture of the state of the air in the city. However, the relevant services of the city council and access to the appropriate server work.



**Fig. 2. Emissions of OJSC NPK “Galychyna” for the period from 2016 to 2020**

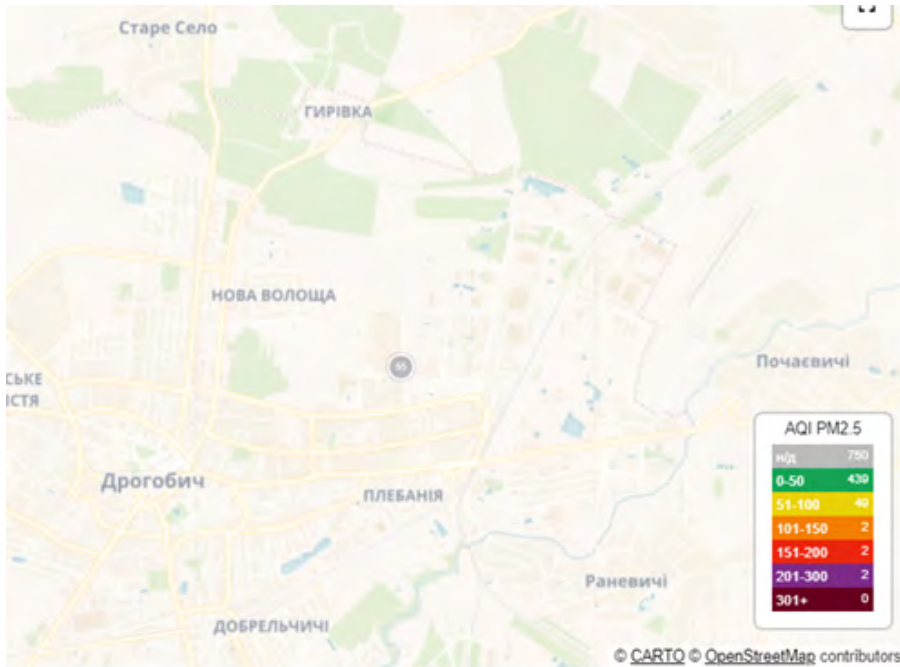


**Fig. 3. Structure of air emissions in Drohobych**

Thus, the city of Drohobych has a well-developed industrial and transport infrastructure. Atmospheric air control is carried out only at the level of regional administration. At the same time, the city authorities are making efforts to create a system for monitoring the state of the environment. The first step is to install an automated control post. Prerequisites for the creation of a fully functioning surveillance system are also sufficient informatization, introduction of technologies allowing online monitoring of the work of local governments.

## **RESULTS OF THE RESEARCH AND ITS DISCUSSION**

The proposed air monitoring system may include 4 observation posts located in the most representative places in terms of environmental pollution. It must take into account two main factors of pollution – pollution by industrial enterprises and pollution by road. The substantiation of the locations of the posts is determined by the zoning of the city with the allocation of districts depending on the degree of their pollution. The city has the following main areas: industrial zone, traffic zone and residential area.

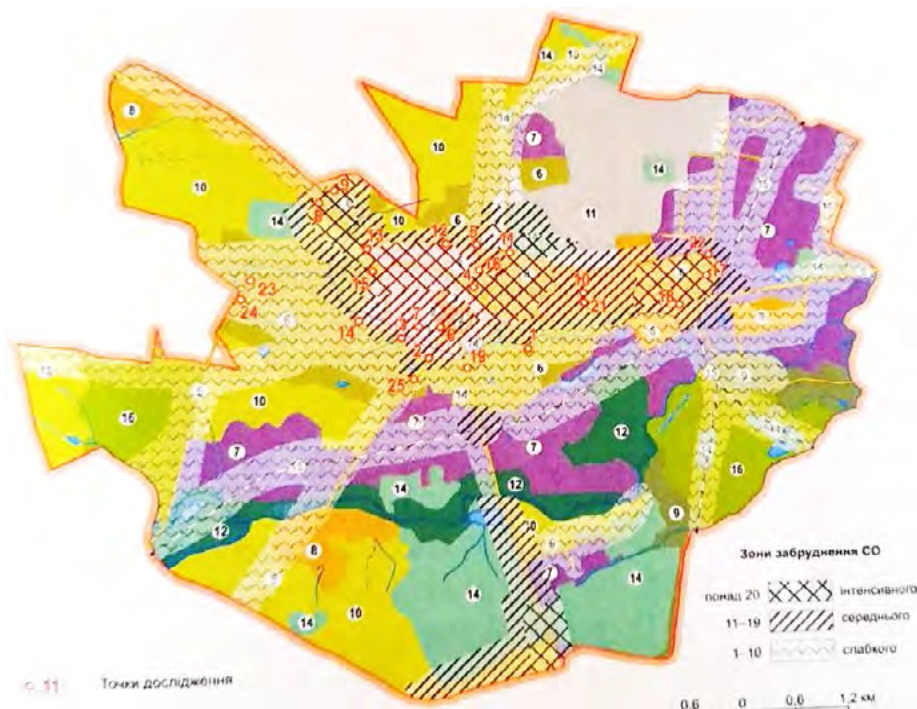


**Fig. 4. Post of control for a condition of atmospheric air on Konovaltsia Street which is not operating today. (<https://www.saveecobot.com/maps/drohobych>)**

Air pollution and its condition is determined by the industries operating in the city. And the created monitoring system should clearly monitor air pollution by these substances. The task of post No. 1 should be sampling and control of pollution by industrial enterprises. The industrial zone should include the area with the largest air pollutants located on it. This is the area of Boryslavska, Fabrychna and Truskavetska streets. The second zone is the so-called "railway-industrial area", which covers Zluky Square, Haydamatska Street, Rychtytska Street, Vokzalna Street, Vokzalny Lane, part of the V. Velyky Street from "Silpo", part of the Hrushevskoho Street from a garment factory, part of Stryjska Street 16 school, Industrialna Street. With regard to industrial enterprises, it is advisable to locate one of the posts on the border of the sanitary protection zone. Such a post will demonstrate the level of pollution of an industrial enterprise. The approximate location may be at the address of the Boryslavska Str. 45.

At the same time, during the independence of Ukraine, the transport load in the city has significantly increased. The number of private transports has increased, which in turn has led to an increase in traffic in the central part of the city. Atmospheric air pollution also increased accordingly. Post No. 2 should reflect the state of traffic in the central part of the city. According to research, the highest level of pollution is observed in the central part of the city on the Stryjska, Hrushevskoho, Volodymyr Velykyy, Lesya Ukrainka streets. To assess the impact of traffic, the post should be placed at Sagaidachnoho Street.

The task of post No. 3 is to control the air quality in the residential area of the city. For example, a large residential area is located in a quadrangle formed by Sagaidachnoho, Pylypa Orlyka, Sambirska and Severyna Nalyvayka streets. Accordingly, a post that will show the state of the air in the residential area can be placed at Vasyl Stus Street 14. Using the post No. 4 additional control over the traffic load in the city will be carried out. This function can be performed by a post at Eugene Konvalets Street, 7. The location of observation posts is shown in Fig. 6 [14].



**Fig. 5. Atmospheric air pollution in Drohobych by carbon monoxide emissions**



**Fig. 6. Location of observation posts in Drohobych**

The equipment of observation posts must meet a number of defined requirements. Posts must perform sampling and measurement of pollutant concentrations, processing the results and transmitting them in real time [5-7; 16]. The standard observation post should include a sampling unit, an air analysis unit, a meteorological situation data collection unit, and a radiation pollution data collection unit. The main parameters of the observation post are presented in the table below.

**Table 2. Technical characteristics of the observation post**

<b>Gas analyzers</b>	
<b>Substance</b>	<b>Measuring range</b>
Sulfur dioxide (SO <sub>2</sub> )	0-1.8 mg/m <sup>3</sup>
Nitrogen dioxide (NO <sub>2</sub> )	0-1.7 mg/m <sup>3</sup>
Nitric oxide (NO)	0-0.8 mg/m <sup>3</sup>
Carbon monoxide (CO)	0-15.0 mg/m <sup>3</sup>
Hydrogen sulfide (H <sub>2</sub> S);	0-0.8 mg/m <sup>3</sup>
Ozone (O <sub>3</sub> ) in the range;	0-0.4 mg/m <sup>3</sup>
Ammonia (NH <sub>3</sub> ) in the range;	0-0.8 mg/m <sup>3</sup>
Hydrogen chloride (HCl) in the range;	0-4,5 mg/m <sup>3</sup>
Ethylene (ethene) (C <sub>2</sub> H <sub>4</sub> ) in the range;	0-8 mg/m <sup>3</sup>
<b>Measuring instrument for mass concentration of aerosol particles (suspended solids)</b>	
<b>Particles PM<sub>10</sub></b>	0.01-2.5 mg/m <sup>3</sup>
<b>PM<sub>2.5</sub> particles</b>	0.01-1.5 mg/m <sup>3</sup>
<b>Gamma radiation detection unit</b>	
<b>Measurement of ambient dose equivalent power (ADEP) of gamma radiation</b>	0.01 μSv/h to 1.0 Sv/h
<b>Meteorological complex</b>	
Determination of wind speed and direction, atmospheric pressure, air temperature, relative humidity, precipitation, precipitation intensity, type of precipitation, solar radiation, lightning discharges.	

The created system of observation posts can be connected to the already existing network created by the city council. The data can thus be quickly processed and viewed on request by any city resident. In addition to the functions of informing about the state of the air will also perform a number of other functions. In particular, this includes responding to the emergence of additional factors, expansion and re-equipment of industrial enterprises, assessment of the growth of transport load, to develop programs to improve the environment in the city.

## CONCLUSIONS

The problem of air pollution remains acute in many regions of Ukraine. The main factors of air pollution are existing enterprises and transport. In such conditions, constant monitoring of atmospheric air becomes important. In this regard, the European experience of implementing automated air monitoring systems is becoming valuable [17, 18]. Today, such projects are being implemented both in large cities of Ukraine and in cities of district significance. The city of Drohobych is the second most important settlement in the Lviv region. The city's industrial potential has declined since the Soviet period, but a number of the city's enterprises remain powerful producers. The city is gradually increasing the traffic load. In the case of resumption of industrial enterprises, as well as further growth of traffic load, air pollution will increase every year. Therefore, an effective monitoring system is needed to support effective management decisions on landscaping, construction and traffic management. Such a system should monitor the current state of the air, be ready for the growth of production and transport load, should be able to flexibly switch to the control of new dangerous areas, inform the public about air quality in real time. For the functioning of the system, it is proposed to allocate areas with the highest risk of pollution – areas of industrial enterprises, areas with a high level of traffic load, as well as a residential area. It is necessary to determine the list of controlled parameters on the basis of data on the work of



enterprises and transport. After the selection of districts, the next step is to install automated posts in each of them, which will control the list of pollutants defined in each district. The proposed monitoring system will improve the planning of environmental measures, landscaping, development of the territory.

## REFERENCES

1. Industry of Drohobych [Electronic resource]. Retrieved from: <http://surl.li/chndp> (accessed date 25.09.2021) (in Ukrainian)
2. Air Pollution in Przemyśl: Real-time Air Quality Index Visual Map [Electronic resource]. Retrieved from: <https://aqicn.org/map/przemysl/> (accessed date 25.09.2021)
3. Handbook on the Implementation of EC Environmental Legislation, Section 3 – Air Quality Legislation. [Electronic resource]. Retrieved from: <https://ec.europa.eu/environment/%20archives/enlarg/handbook/handbook.pdf> (accessed date 25.09.2021)
4. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (official translation on the website of the Verkhovna Rada of Ukraine). [Electronic resource]. Retrieved from: [https://zakon.rada.gov.ua/laws/show/994\\_950#Text](https://zakon.rada.gov.ua/laws/show/994_950#Text) (accessed date 25.09.2021) (in Ukrainian)
5. Yang, Y. and Li, L. A smart sensor system for air quality monitoring and massive data collection. *Information and Communication Technology Convergence (ICTC)*. 2015. P. 147–152.
6. Chuhai A.V. Environmental monitoring. Methods of measuring environmental parameters. Lecture notes. Odessa: TES, 2014. 66 p. (in Ukrainian)
7. Wonohardjo, E.P., Kusuma, G.P. Air pollution mapping using mobile sensor based on internet of things. *Procedia Computer Science*. 2019. Vol. 157. P. 638–645. <https://doi.org/10.1016/j.procs.2019.08.224>
8. About the automated system of ecological monitoring of atmospheric air in the city of Brovary of the Kiev region. [Electronic resource]. Retrieved from: <https://ecolog-ua.com/articles/pro-avtomatyzovanu-systemu-ekologichnogo-monitoryngu-atmosfernogo-povitrya-u-mistibrovary> (accessed date 25.09.2021)
9. Koltsov M., Shevchenko L. Atmospheric air quality monitoring: Ukrainian and international experience. [Analytical note]. Kyiv: Open Society Foundation, 2018. P. 13. (in Ukrainian)
10. State sanitary rules for protection of atmospheric air of populated areas (from pollution by chemical and biological substances). Order of the Ministry of Health of Ukraine of July 9, 1997. No. 201.
11. Regional report on the state of the environment in the Lviv region in 2020 [Electronic resource]. Retrieved from: <https://drive.google.com/file/d/1g1KQADR> (accessed date 25.09.2021) (in Ukrainian)
12. Report on the results of monitoring the natural environment of Lviv region [Electronic resource]. Retrieved from: <http://surl.li/chnee> (accessed date 25.09.2021) (in Ukrainian)
13. Atmospheric air quality: a brief description of the EU Directives and the timetable for their implementation. Kyiv: EU Technical Assistance Project “Additional Support of the Ministry of Ecology and Natural Resources of Ukraine in the Implementation of Sectoral Budget Support”, 2015. 15 p.
14. Level of air pollution in the city of Drohobych. [Electronic resource]. Retrieved from: <https://www.saveecobot.com/maps/drohobych> (accessed date 25.09.2021). (in Ukrainian)
15. Catalog of SMART CITY services. [Electronic resource]. Retrieved from: <https://drohobych-rada.gov.ua/smart-city/> (accessed date 25.09.2021). (in Ukrainian)
16. Idrees Z., Zheng L. Low cost air pollution monitoring systems: A review of protocols and enabling technologies [Electronic resource]. *Journal of Industrial Information Integration*. 2020. Vol. 5. Retrieved from: <https://www.sciencedirect.com/science/article/abs/pii/S2452414X19300792>

17. Poletaeva L.M., Safranov T.A. Environmental monitoring. Study guide. K. : KNT, 2007. 172 p. (in Ukrainian)
18. Hryb O.M., Chuhay A.V. Automated monitoring and assessment of air quality. Methodical instructions for preparation of students on specialties 101 “Ecology” and 103 “Earth Sciences”. Odessa, ODEKU, 2019. 58 p.
19. Marinov, M.B., Topalov, I., Gieva, E. and Nikolov, G. Air quality monitoring in urban environments. 39th International Spring Seminar on Electronics Technology (ISSE). Pilsen, 2016. P. 443–448.
20. Postolache, O.A., Pereira, J.M.D., Girao, P.M.B.S. Smart sensors network for air quality monitoring applications. *IEEE Trans. Instrum. Meas.* 2009. Vol. 58. P. 3253–3262. <https://doi.org/10.1109/TIM.2009.2022372>
21. Terletska O.V. Geoecological condition and ecotourism prospects of Drohobych urban system. Lviv: Prostir-M Publishing House, 2020. 200 p.

## АНОТАЦІЯ

### РОЗРОБКА СИСТЕМИ МОНІТОРИНГУ АТМОСФЕРНОГО ПОВІТРЯ МІСТА ДРОГОБИЧА

Проблема забруднення атмосферного повітря в українських містах продовжує залишатися актуальною. У цілому ряді міст вона пов’язана з діяльністю працюючих там підприємств, а також зі зростаючим транспортним навантаженням. Саме зростання рівня загазованості у великих містах України та спровоковані цим такі негативні явища, як смог, викликали потребу у контролюванні та відслідковуванні стану атмосферного повітря. У містах-мільйонниках та обласних центрах почали створювати програми контролю та моніторингу стану атмосферного повітря. Починають запроваджуватися системи моніторингу атмосферного повітря і у районних центрах. Зокрема такі пости встановлюються і у районних центрах Львівщини. Проте 1 пост на місто не завжди може адекватно відобразити ситуацію із забрудненням атмосферного повітря.

У країнах Європейського союзу сьогодні реалізується підхід з використання постів автоматизованого контролю за станом повітря, що вимірюють певний визначений перелік показників. В Україні система моніторингу крім стандартних показників може передбачати також вимірювання ряду специфічних показників, пов’язаних з діяльністю відповідних галузей.

Місто Дрогобич є другим за значенням населеним пунктом у Львівській області. Промисловий потенціал міста знизився порівняно з радянським періодом, проте ряд підприємств міста залишаються потужними виробниками. У місті поступово зростає транспортне навантаження. У разі відновлення роботи промислових підприємств, а також подальшого зростання транспортного навантаження, забруднення повітря щороку зростатиме. Тому для підтримки ефективних управлінських рішень з озеленення, забудови і регулювання транспортного навантаження потрібна ефективно діюча система моніторингу. Така система повинна відслідковувати поточний стан повітря, бути готовою до зростання обсягів виробництва та транспортного навантаження, повинна мати можливість гнучко переключатися на контроль нових небезпечних ділянок, інформувати населення про якість повітря у режимі реального часу. Для функціонування системи пропонується виділити райони з найвищою небезпекою забруднення – райони роботи промислових підприємств, райони з високим рівнем транспортного навантаження, а також селітебну зону. На основі даних про роботу підприємств та транспорту необхідно визначитися з переліком контрольованих параметрів. Після виділення районів наступним кроком є встановлення у кожному з них автоматизованих постів, що контролюватимуть визначений у кожному районі перелік забруднюючих речовин. Запропонована система моніторингу дозволить покращити можливості планування природоохоронних заходів, заходів з озеленення, забудови території.

**Ключові слова:** екологічна освіта, екологізація, сталий розвиток, екологічні проблеми, система освіти, освітні технології.