

Air pollution of the largest cities in the Volyn region: preconditions, consequences and ways of solution of this problem

*Mykhailo M. Melniichuk*¹,

PhD (Geography), Associate Professor, Department of Physical Geography,
¹Lesya Ukrainka Volyn National University, 9 Potapova St., Lutsk, 43021, Ukraine,
e-mail: melniichuk.mm@gmail.com, <https://orcid.org/0000-0002-7258-2869>;

*Victoriia V. Horbach*¹,

MSc, Department of Physical Geography,
e-mail: vichorbach@gmail.com, <https://orcid.org/0000-0002-9532-1610>;

*Liudmyla M. Horbach*²,

PhD (Economics), Associate Professor, Director of the ²Vyacheslav Lipinski Institute of Volyn JSC «MAUP»,
8 Copernicus St., Lutsk, 43025, Ukraine,
e-mail: ludmilahorbach@gmail.com, <https://orcid.org/0000-0002-5977-6474>;

*Oleksandr P. Vovk*¹,

PhD (Geology), Associate Professor, Department of Physical Geography,
e-mail: vovk.oleksandr@vnu.edu.ua, <https://orcid.org/0000-0002-1509-0905>

ABSTRACT

Formulation of the problem. Air pollution is one of the biggest modern ecological problem, which aggravates with process of urbanization, industrial development, increasing number of vehicles, etc. So that, the article is devoted to the study the of air pollution in the largest cities of the Volyn region: Lutsk, Kovel, Novovolynsk and Volodymyr-Volynskiy. The purpose of the article is to estimate state and quality of the air in the largest cities of the Volyn region, discover the main sources of air pollution, characterize the effects of pollution on people health and environment, propose measures for solving this problem.

Review of previous publications and studies. State of the air pollution in the urban areas of the Volyn region became the subject of scientific interest of many scientists. Hulai L. D., Karaim O. A. and Syniuk, A. Yu. researched ecological state of air basin and structure of sources of air pollution in the Novovolynsk City. Panasiuk M. V. and Hulai L. D. analyzed air quality in the Kovel district and Kovel City. Problems of air pollution were investigated in the studies of Kiptenko Ye. M., Kozlenko T. V. and Molchak Ya. O., Fesiuk V. O., Kartava O. F. Moreover, Poruchynska, I. V. in her publication explored ways of reducing air pollution by vehicle in the Volyn region.

Methods. The most common methods in the research were analysis and synthesis, correlations and regressions, generalization and comparison. Moreover, to study the quality of air basin in the largest urban area – Lutsk City, the authors calculated index of air pollution.

Results. The study defined that the main source of air pollution in the urban systems are automobiles, which produce into the atmosphere 85-95 % of all emissions. Furthermore, stationary sources such as industrial enterprises and utility companies also pollute air basin of cities with hazardous substances. However, the amount of pollutants from these sources in the Lutsk City and Volodymyr-Volynskiy City slowly decreases. The authors researched that the air basin in Lutsk City is exposed to the greatest anthropogenic loading. According to the calculation of the air pollution index, city's air basin belongs to the quality class «polluted air». Consequences of air pollution are quite different and have impact on environment and economic complex. Besides, poor air quality can cause different diseases. To solve this problem the authors propose to reconstruct and modernize enterprises' treatment systems, to increase the number of environmental friendly public transport, to increase the areas with greenery, to introduce green logistics in transportation. The authors concluded that air basin in the most urbanized areas of the Volyn region is quite polluted, which caused by using vehicles and functioning of manufacture. So that, it is suggested measures to reduce the amount of emission from different source of pollution.

Scientific novelty and practical significance. The main preconditions and trends of modern changes in air quality of the largest cities in the Volyn region was researched for the first time. Furthermore, the authors identified the main sources of air pollution, which have affected the quality of urban air basins during recent years. In addition, index of air pollution in the Lutsk City was calculated for the period 2015-2020. The article proposes measures to improve air quality and reduce emissions from stationary and mobile sources of pollution.

Keywords: *air pollution, pollutants, urban areas, sources of air pollution, air pollution index, specific urban diseases.*

In cites: Melniichuk M. M., Horbach V. V., Horbach L. M., Vovk O. P. (2022). Air pollution of the largest cities in the Volyn region: preconditions, consequences and ways of solution of this problem. *Visnyk of V. N. Karazin Kharkiv National University, series "Geology. Geography. Ecology"*, (56), 214-224. <https://doi.org/10.26565/2410-7360-2022-56-16>

Formulation of the problem. Atmospheric pollution is one of the biggest environmental problems today. With the rapid development of science and technology, industrial production and increasing the number of vehicles, the level of air pollution is growing rapidly, especially in urban settlements, where

small areas are concentrated large population and concentrated production. According to the World Health Organization, anthropogenic air pollution kills about 9 million people worldwide each year [20]. Therefore, the problem of air pollution in urban systems requires detailed study in order to minimize

the negative impact on human life and the environment.

Volyn region is a typical agro-industrial region of Ukraine with a weak development of industrial production, a scattered settlement network and the absence of large cities. In terms of pollutant emissions, the region belongs to one of the cleanest regions of Ukraine and is second only to Zakarpattia and Chernivtsi regions in terms of pollution by stationary sources and Luhansk and Chernivtsi – in terms of mobile pollution [19]. Cities are the largest centers of air pollution in the study region, due to the significant development of industrial production, the concentration of large populations and vehicles, and so on. In the context of intensification of urbanization, the study of the problem of air quality in urban areas is one of the most important tasks, the solution of which will help to preserve an environment conducive to human life and health.

Analysis of recent research and publications.

The information base of the study consisted of the works of many scientists who studied the state of the atmospheric air of individual settlements and territories of Volyn region. Problems of atmospheric air pollution are covered in the works of Ya. O. Molchak, V. O. Fesiuk, O. F. Kartava [7], E. M. Kiptenko, T. V. Kozlenko [4]. L. D. Gulai, O. A. Karaim and A. Yu. Siniuk studied the ecological state of the air in Novovolynsk [2]; M. V. Panasiuk and L. D. Gulai studied the air basin of Kovel district [9]. The theoretical basis of the article is the work of S. A. Plahotnii [10], V. V. Tarasova [16], Yu. V. Knysh [5], Y. L. Kozubenko [6], S. M. Smirnova, V. N. Smirnov, O. O. Shapovalov [14]. Among foreign scientists, the works of S. Chen, D. Zhang [17], E. D. Lozano-Sabido, E. A. Berios-Barcenas [18], etc. are devoted to the study of atmospheric pollution and its consequences. In addition, the study used and processed statistical data of the Main Department of Statistics in Volyn region, Volyn regional center for hydrometeorology, the State Statistics Service of Ukraine, etc.

Coverage of previously unresolved parts of the overall problem. The problem of air pollution in urban systems of Volyn region is covered in many of fundamental works on ecology and geography. However, the current state of the air basins of the largest cities in the region has not been sufficiently studied in the scientific literature. Therefore, for the first time in the article the main reasons for the change in air quality of the considered urban areas are clarified and the main modern sources of pollution of their air basins are revealed. In addition, the index of air pollution in the regional center of the region – Lutsk for the period 2015-2020 was calculated, and it was established that the atmospheric city basin belongs to the class of “polluted”.

Formulation of the purpose of the article. The

aim of the work is to study the condition and quality of the air basin of the largest cities of Volyn region, taking into account the preconditions and consequences of air pollution. In accordance with the goal, the following tasks were solved:

- describe the features of the location of the studied cities;
- identify the main sources of emissions of impurities into the air basins of settlements;
- analyze the dynamics of pollution of the cities;
- calculate the index of air pollution in Lutsk;
- identify the most polluted areas of the regional center and the main stationary sources of pollution;
- find out the consequences of air pollution in cities;
- propose measures to improve the air quality of the studied areas.

Research methodology. The methodological apparatus of the work is based on the use of methods of analysis and synthesis, correlation and regression, generalization and comparison. To study the state of the air in Lutsk, one of the most common methods was chosen – to determine the index of air pollution by a single substance, the index of air pollution by 5 substances and a comprehensive index of pollution. The index of air pollution by a single substance is calculated as the ratio of the concentration of this substance in the air to the maximum allowable norm (1.1). It is used to compare the level of air pollution in individual regions or cities, as well as to compare the level of air pollution with different substances

$$API_i = (C_i \div TLV_i)^{K_i}, \quad (1.1)$$

where C_i is the average concentration of the i -th substance in the air during the study period; TLV_i – threshold limit value of the i -th substance in the air; K_i is a constant that changes its values depending on the hazard class of the substance. If the pollutant belongs to the 1st class of danger, the average value of the constant is 1.5; to the 2nd – 1.3; to the 3rd – 1.0; to the 4th – 0.85.

The air pollution index (API_5) is used for the complex analysis of the air basin composition. The index we calculated for 5 pollutants, the concentration of which is the highest in the air of the study area by formula 1.2 [10, p. 10].

$$API_5 = \sum_{i=1}^5 API_i, \quad (1.2)$$

where 5 is the number of substances for which the index is calculated, API_i is the index of air pollution by a particular substance. In case of need of the expanded research of structure of atmospheric air calculate the complex index of atmospheric pollution (CIAP) according to the formula 1.3 for which calculation the quantity of substances is not limited. (1.3)

$$CIAP = \sum_{i=1}^n API_i, \quad (1.3)$$

where n is the number of substances for which the index is calculated, API_i – the index of air pollution by a particular substance. According to the obtained results of calculations, the class of air pollution is determined. If the values obtained are less than 2.5, the atmosphere is considered clean; 2.5-7.5 - slightly polluted atmosphere; 7.5-12.5 – polluted atmosphere; 12.5-22.5 – heavily polluted atmosphere; 22.5-52.5 – highly polluted atmosphere; over 52.5 – extremely polluted atmosphere.

Presentation of the main research material. Volyn region is located in the extreme north-west of Ukraine and borders with the Republic of Poland, the Republic of Belarus, Rivne and Lviv regions, its total area is 20,144 thousand km². There are 11 cities in the region (1 of them is a medium-sized city and 10 small cities) and 22 urban-type settlements. The largest cities are: Lutsk, Kovel, Novovolynsk, Volodymyr-Volynskiy (Fig. 1).

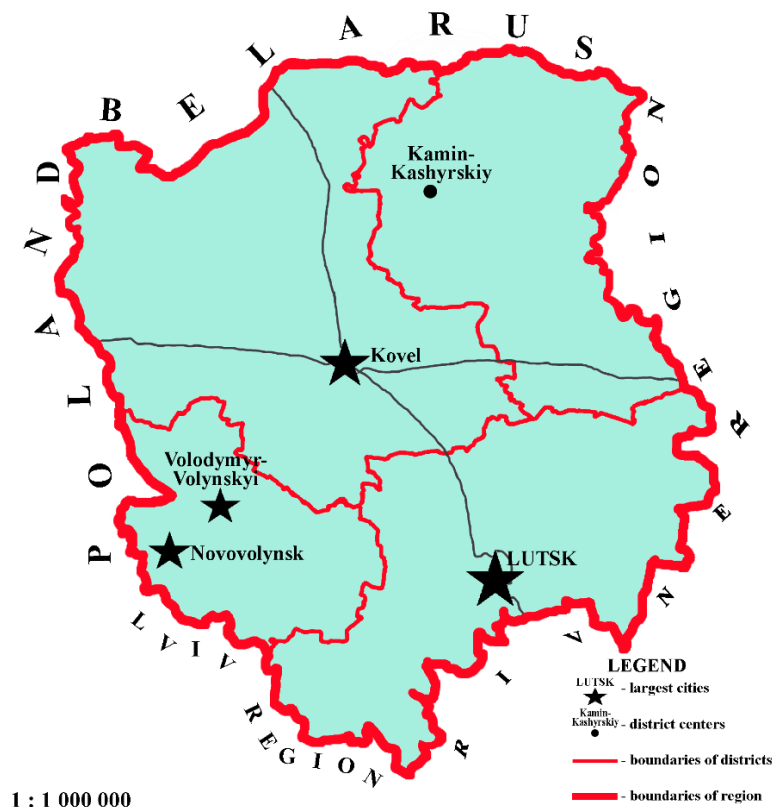


Fig. 1. Location of the largest cities of Volyn region

Due to the lowland position and significant wetlands in the north of the region, the settlement network is quite scattered, and the settlements are small. The largest settlements are concentrated mainly in the southern part of the region within the Volyn Upland, where natural conditions are more favorable for farming and industrial development, there are deposits of combustible and non-metallic mineral resources. Thus, most of the considered cities are located in the south of the region, in particular, the city of Novovolynsk was formed in the place of coal mining of the Lviv-Volyn coal basin, the city of Volodymyr-Volynskiy is an important historical and cultural center of Volyn, Lutsk is the administrative center of the region. Only the city of Kovel lies in the central part of the Volyn region, within the Polesian lowland, and is a major railway transport hub. It should be noted that the atmosphere of Kovel has the best ability to disperse pollutants in the air, and the processes of accumulation of harmful substances in

the air are most actively developing in Volodymyr-Volynskiy [1, p. 65]. In general, the natural conditions of Volyn region are favorable for the dispersion of pollutants in the air, reducing their concentration and self-cleaning of the atmosphere. In particular, there are no significant orographic obstacles to the movement of air masses in the study area. In addition, the processes of dispersion of pollutants in the atmosphere are affected by wind speed, which averages from 2.5 to 4.5 m/s during the year. In winter, westerly and south-westerly winds prevail, in summer – westerly and north-westerly do [8, p. 54]. The number of days with calm weather is small, however, in the recent years, there has been a general trend towards increasing the duration of such conditions. A negative aspect that impairs the self-cleaning properties of the atmosphere by trapping pollutants within cities is urban infrastructure, such as high-rise buildings, narrow streets, and so on. Another positive prerequisite that helps to reduce the concentration of

pollutants in cities is their small area, small population and small areas occupied by multistory buildings (Table 1). In general, the region belongs to the regions with one of the lowest levels of urbanization in Ukraine. Thus, in 2020, 52.3 % of the population

lived in cities, of which 40.4 % – in Lutsk. It should be noted that there are no large cities in the region, only the city of Lutsk belongs to the medium-sized cities and has a total area of 42 km². The largest area is the city of Kovel – 47 km².

Table 1

The largest cities of the Volyn region

City	Area, km ²	Number of people, thousand people	Population density, people/km ²	Proportion of the urban population, %	Proportion of the whole population, %
Lutsk	42	217,2	5 171,4	40,4	21,1
Kovel	47	68,0	1 446,8	12,7	6,6
Novovolynsk	17	55,1	3 241,2	10,3	5,4
Volodymyr-Volynskyi	17	38,1	2 241,2	7,1	3,7

*calculated by authors based on the statistics [15, p. 30]

Based on the above, we summarize that the concentration of pollutants in the cities of Volyn region depends on the amount and composition of emissions from transport and industrial enterprises, building features, congestion of roads, location of enterprises relative to the prevailing wind directions and so on.

Due to the active development of transport, in Ukraine, cars emit about 6.5 million tons per year or 37% of all harmful emissions into the air, and in some cities they outnumber all others [6, p. 87]. In general, the level of air pollution in the studied cities of Volyn region is quite high and has a general upward trend. The largest amount of the pollutants in the air basin of cities is supplied by mobile sources of pollution, in particular, cars, which account for more than 85-95 % of all emissions. Such a high share of mobile sources in the structure of air pollution is due to the concentration of a large number of road transport in cities, significant indicators of passenger and freight turnover, as well as the congestion of roads.

A working car emits carbon monoxide, nitrogen oxides, as well as more than 200 compounds with toxic effects [14, p. 64]. Cars emit the most of the pollutants into the atmosphere at idle, during braking and speeding. Long-lasting cars deliver significantly more impurities to the air than new ones, due to equipment wear after 5-10 years of use. In addition, such sources are dangerous because they emit pollutants into the surface layer of the air where the population lives. It should be noted that since 2016, monitoring of emissions from mobile sources is not carried out. As of 2015, 10 300.7 tons of impurities were released into the air of Lutsk by mobile sources, which is 92 % of all emissions, in Volodymyr-Volynskyi – 1 215.7 tons (89.7 %), in Kovel – 3 452.2 tons (90 %), in the city of Novovolynsk – 2 097.4 (91.4 %). Despite the small share in the structure of emissions, stationary sources of pollution supply the atmosphere of cities no less harmful pollutants. Note

that in accordance with Article 10 of the Law of Ukraine «On Protection of Atmospheric Air», enterprises, institutions, organizations and citizens – business entities that emit pollutants into the atmosphere and whose activities are related to the influence of physical and biological factors on its condition, are obliged to provide uninterrupted effective work and maintenance in a serviceable condition of constructions, the equipment and the equipment for clearing of emissions and reduction of levels of influence of physical and biological factors, etc. [3]. However, a significant number of enterprises and organizations produce pollutants into the atmosphere due to the moral and technical obsolescence of their treatment plants. On average, in these cities, there are 3.9 kg of emissions per inhabitant, and 12 tons of impurities from stationary sources of pollution per 1 km² of urbanized territory. The highest indicators of the concentration of pollutants during 2015-2020 are observed in Lutsk, the lowest – in Volodymyr-Volynskyi (Fig. 2).

Note that in Lutsk there is a positive trend in the amount of pollutant emissions. In particular, in 2015, 0.95 thousand tons of impurities were discharged from stationary sources into the air basin, in 2018 – only 0.4 thousand tons, in 2020 emissions increased slightly and amounted to 0.7 thousand tons. A slight reduction in emissions is also typical for Volodymyr-Volynskyi. The phenomenon is due to the reduction of industrial production in cities, the closure of a large number of enterprises, as well as the improvement of sewage treatment plants of individual organizations. In the cities of Novovolynsk and Kovel, on the contrary, the volume of impurity discharges increased compared to 2015. This feature is due to the deterioration of sewage treatment plants of most enterprises in the cities.

During the study period, emissions increased significantly in the industrial city of Novovolynsk,

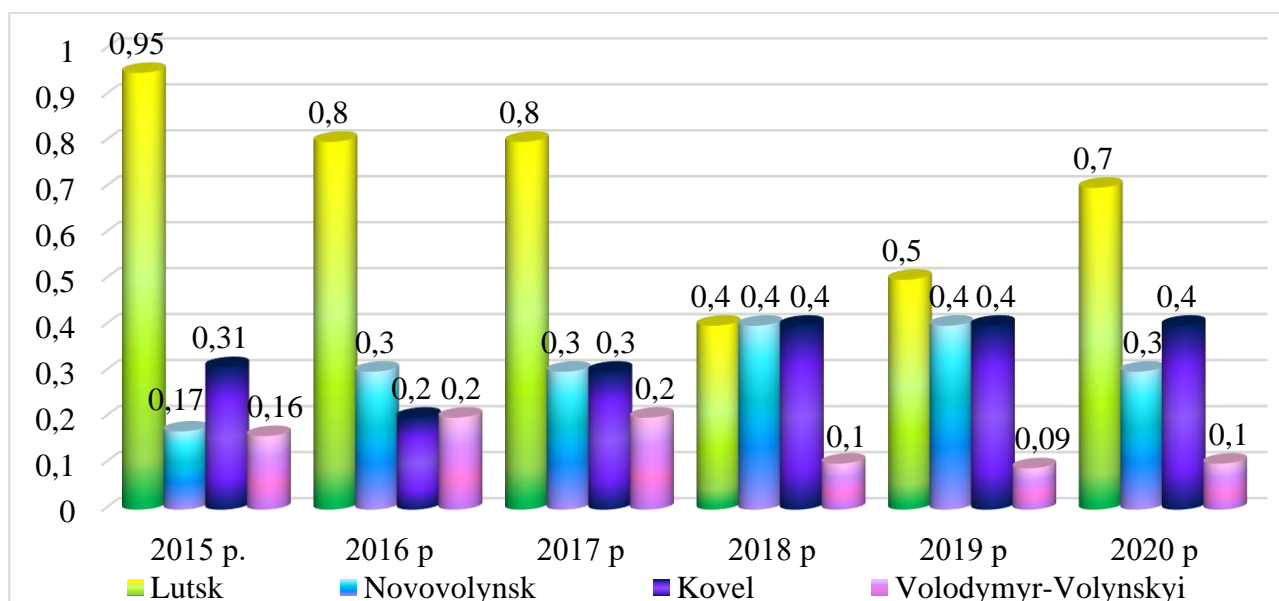


Fig. 2. Dynamics of emissions of pollutants from stationary sources of pollution in the largest cities of the region during 2015-2019, thousand tons (*done by authors based on the [12, p. 9; 13, p. 10])

which specializes in coal mining. The city's air quality is monitored at two checkpoints on Peremohy Avenue and Sokalska Street. Note that in 2015, 0.17 tons of impurities were released into the atmosphere of the settlement, and in 2020 – 0.3 tons. The most of the pollutants enters the air basin from the coal mining association «Volynvugillya» about 40 % of emissions from the stationary sources, furniture company «BRV – Ukraine», utility company «Novovolynskteplokomunenerho» and woodworking company «Kronospan UA» [2, p. 64-65]. Pollution rates in Kovel are consistently high. The settlement is an important railway junction of Ukraine, so, a large amount of the pollutants enters to the city air from the rail transport. The largest stationary polluters of the Kovel air basin are OJSC Kovelskyi miasokombinat (Kovel Meat Processing Plant), which supplies carbon monoxide to the atmosphere, and Kovel Passenger Car Depot (which produces carbon oxides and dust) [9, p. 153]. However, as in other cities of the region, the main source of pollution is road transport.

The smallest amount of the pollutants from stationary sources enters the air basin of Volodymyr-Volynskyi. The phenomenon is associated with much less development of industrial production of the settlement than in other studied cities. The main enterprises that emit pollutants into the atmosphere include: LLC «Gerbor-Holding», PJSC «Luga», LLC «Khlibozavod» (Bread-baking plant), Privately held company «Sklo-Tsentr» (Glass Center), Privately held company «BTR-S». These are mainly agricultural organizations and the small processing enterprises, that produce a relatively small amount of the pollutants into the atmosphere. The administrative center of the Volyn region – Lutsk – suffers the

greatest technogenic load. The city has concentrated powerful industrial productions of the processing industry, developed a dense transport network, 21.1 % of the region's population and a significant number of cars. Systematic observations of air quality are carried out at three observation points (Rivnenska Street, Konyakina Street, Chopin Street), where observations are carried out four times a day (Fig. 3).

During 2020, the largest number of exceedances of the TVL in Lutsk was observed in the content of nitrogen dioxide, formaldehyde and phenol, which is associated with a large number of vehicles on the roads of the city. For the convenience of analyzing the quality of the air basin of Lutsk, we calculate the index of air pollution by individual substances, as well as the complex index of air pollution (Table 2).

The total index of air pollution in Lutsk in 2020 in terms of the content of the five substances with the highest concentration (nitrogen dioxide, formaldehyde, phenol, nitric oxide and dust) is 7.1, which corresponds to the state of the atmosphere «polluted». According to the calculations of the complex index of atmospheric pollution (CIAP), the air of the administrative center of the region also belongs to the polluted and is 7.5. It should be noted that such indicators of the level of air pollution in Lutsk are the lowest in the last six years. The phenomenon is explained by the reduction of road traffic on the roads of the settlement, the reduction of industrial production by some enterprises due to quarantine restrictions during March-December 2020. The main share of the pollutants' emission in Lutsk is accounted for by road and accounts for 92-95 % of all emissions. According to Ya. O. Molchak, V. O. Fesiuk and O. F. Kartava, the most polluted areas are large

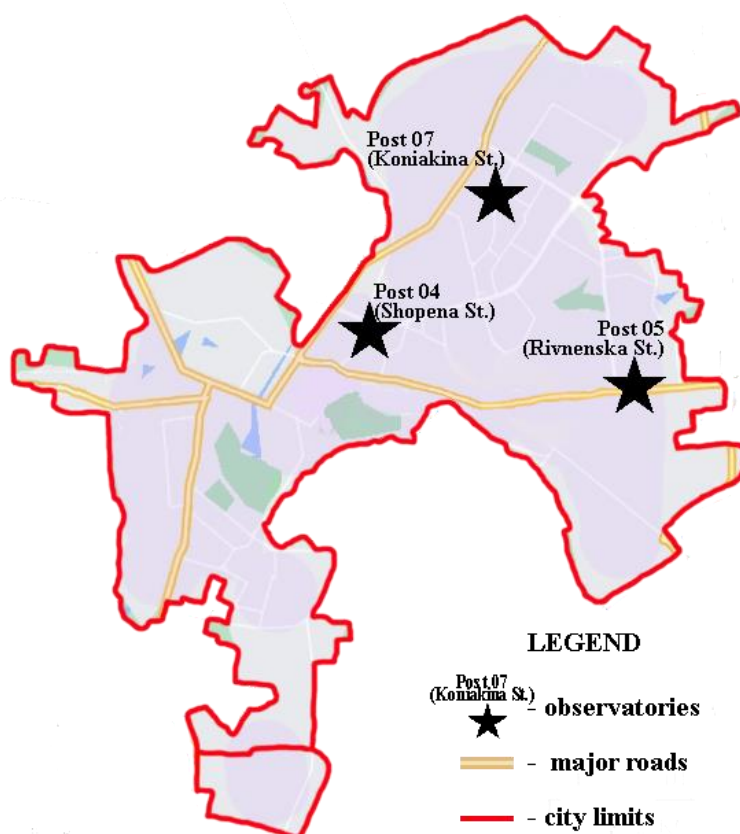


Fig. 3. Skeleton-map of the location of stationary observation posts in Lutsk

Table 2

Index of air pollution by certain substances in Lutsk

Impurities	2015	2016	2017	2018	2019	2020
Dust	0,67	0,67	0,67	0,67	0,67	0,67
Sulfur dioxide	0,04	0,04	0,04	0,04	0,04	0,04
Carbon monoxide	0,39	0,39	0,39	0,39	0,39	0,39
Nitrogen dioxide	2,28	2,28	2,28	2,07	1,87	2,07
Nitric oxide	0,50	0,66	0,66	1,00	0,66	0,50
Phenol	1,45	1,94	1,94	2,46	1,94	1,94
Formaldehyde	2,46	3,00	3,58	4,17	2,46	1,94
API_{general}	7,36	8,55	9,13	10,37	7,60	7,12
CIAP	7,73	8,92	9,5	10,74	7,97	7,55

*calculated by authors based on data from the Volyn Regional Center for Hydrometeorology

transport interchanges, the road Zluky Square – Old Market – Parkova Street, the road Vidrozhennia Avenue – Rivne Street, departure street Shevchenko – street Kovelska – Volodymyrska, as well as the central streets of the city (Volia Ave., Vynnychenko St., Peremohy Ave., Bohdan Khmelnytsky St., etc.) [7, p. 218].

Despite the small share of stationary sources of pollution, emissions from them are quite dangerous, and some require pre-treatment. The largest stationary sources of pollution include the Hnidavskyi tsukrovnyi zavod (Gnidava Sugar Plant), the Lutskteplo utility company, the SKF Ukraine plant, and the Lutskyi remontnyi zavod «Motor» (Lutsk Motor Repair Plant) (Fig. 4).

The largest amount of the pollutants is emitted by stationary sources in the south-eastern industrial area of the city, due to the concentration of many powerful industrial enterprises. As the prevailing winds during the year are north-west and north, such emissions, together with the air masses, are dissipated outside the city. However, we should consider changes in wind direction depending on the pressure field during a year. [4, p. 320]. Thus, in the spring the wind acquires south-eastern and southern rhumbs, which causes pollution of the adjacent areas of the city.

Note that it is rather difficult to trace the differentiation of the level of pollution in the context of individual districts of the city, since the spread of

impurities in the air is influenced by many factors that vary during different time intervals such as day, month and year. Thus, during the period of sugar beet processing at the Hnidavskiy tsukrovyy zavod (end of September – December) the content of pollutants in

the air of the southern part of the city increases. In addition, the content of impurities in the air of a particular area of the city may increase due to a single local impact: road repairs, construction of houses and more.

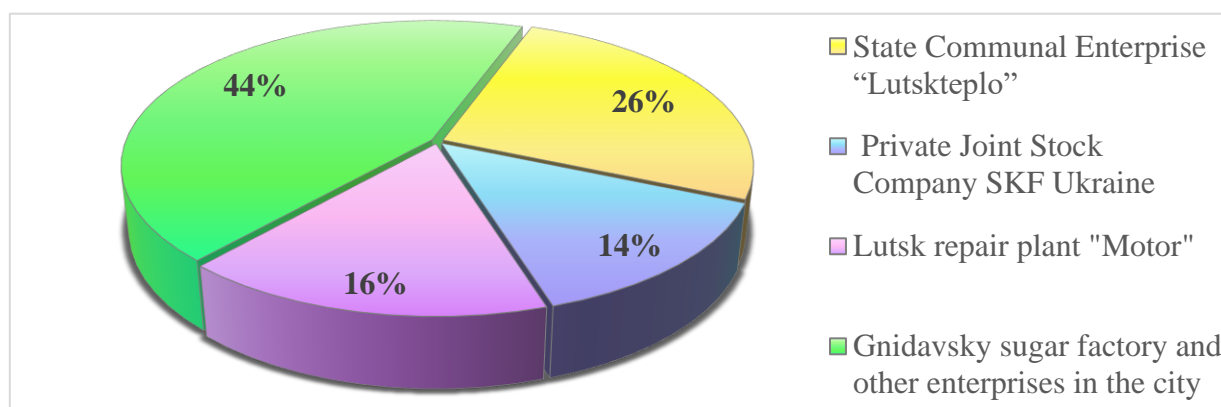


Fig. 4. The structure of emissions of pollutants into the air by stationary sources in 2020, % (*done by authors based on data from the Volyn Regional Center for Hydrometeorology)

Atmospheric air pollution of urban systems has a negative impact on the environment, life and health of the population, the economic complex, etc. (Fig. 5). The consequences of the presence of impurities in the air basin of the considered cities are extremely diverse and can be manifested immediately or have a long-term impact.

Atmospheric air pollution is one of the main environmental causes of poor public health, as the human body is constantly in contact with the air. Depending on the component and the individual characteristics of the organism, caused by the impurities in the air, various pathologies can occur in the human body. It is investigated that at constant action on a human body of exhaust gases of cars on diesel fuel there are disturbances in work of cardiovascular system, risks of formation of thrombi increase, vegetative regulation of heart is broken [18, p. 2]. In particular, the high content of phenols in the air causes the risk of dysfunction of the cardiovascular and nervous systems, liver and kidneys. Formaldehyde causes respiratory, immune and eye troubles. Nitrogen dioxide causes the respiratory system illness [16, p. 24-25]. It is the content of these pollutants in the city of Lutsk that exceeds the permissible norm.

In total, during 2019, the number of deaths in the studied cities was 4,151 people, which is 31.1 % of all deaths in the region. Of these, 65.4 % died from diseases of the cardiovascular system, 15.5 % – from tumors and 1.9 % – from respiratory diseases. Note that the number of deaths has a general tendency to increase, especially from diseases of the cardiovascular system. However, the decrease in mortality from respiratory diseases over the last 5 years is positive.

In addition, it has been proven that an increase in the concentration of pollutants in the air causes a

decrease in efficiency. Thus, with increasing air pollution index (API) every 10 conventional units, labor productivity decreases by an average of 4 % [17, p. 153]. Pollution of the air basin of cities causes material damage to the economy. In particular, impurities in the atmosphere destroy iron products, buildings and other structures. Air pollution is especially dangerous for architectural monuments (temples, castles, monuments, etc.), which can be gradually destroyed by impurities. In general, it is difficult to estimate the damage from air pollution, as it acts together with other factors that damage the products of material industry.

Due to the concentration in a relatively small area of the studied urban systems of a large number of vehicles and industrial production, their air basin receives much more greenhouse gases than the surrounding areas. For example, in 2015, 349.1 tons of methane and carbon dioxide came to the city of Lutsk from stationary and mobile sources of pollution, which is 82 % of the emissions of these gases in the Lutsk region. In 2019, 184.8 tons of investigated greenhouse gases entered the city atmosphere from stationary sources alone.

The constant presence of heat-retaining impurities in the atmosphere, as well as the anthropogenic transformation of landscapes (in particular, the change of the underlying surface) determines the formation of the so-called microclimates on the territory of the considered cities. Therefore, the air temperature in these cities is several degrees higher than in the surrounding areas.

Atmospheric air quality problems in urban areas of Volyn region and their consequences in the process of technogenesis continue to grow and need to be addressed. In general, today most of the systems for

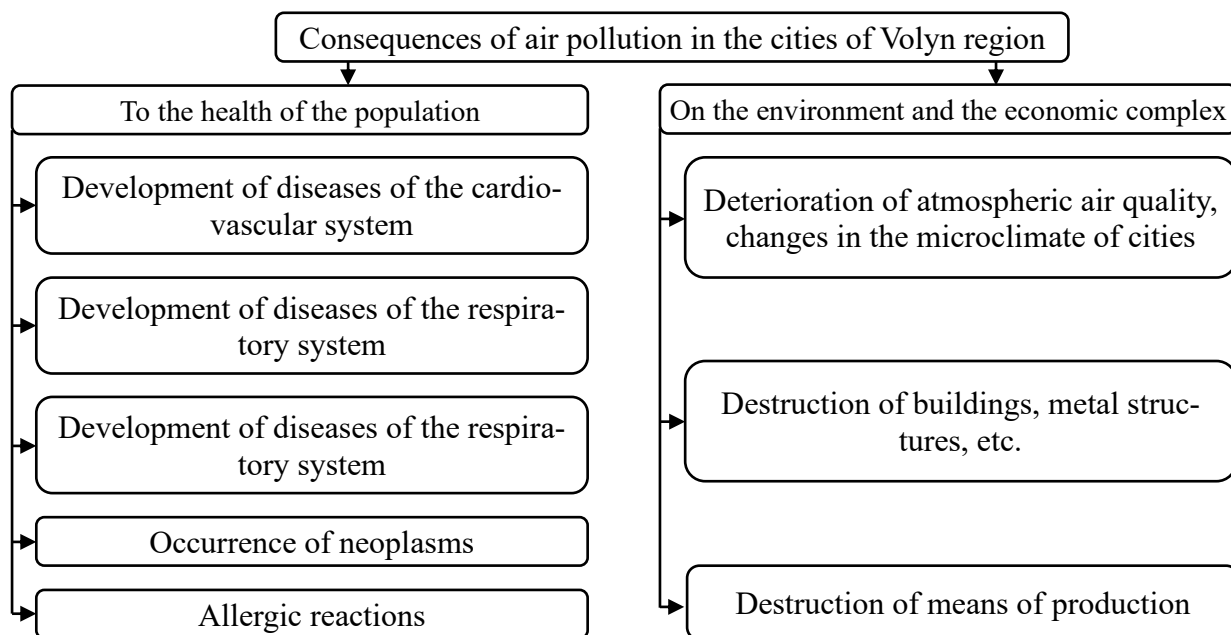


Fig. 5. The main consequences of air pollution in the cities of Volyn region

cleaning stationary sources of air pollution in Volyn region do not clean the emissions at the proper level but allow much of impurities to go into the air. The phenomenon is associated with obsolescence and technical deterioration of sewage treatment plants.

In addition, a significant problem is the uncontrolled and unregulated emissions of road transport. To date, there are only a number of projects and developments that can reduce emissions of impurities into the air, but we do not know radical solution to this problem. The urgent measures to solve this problem include: establishing speeds up to 60 km / h in cities, designing bypass roads for transit transport, equipping new cars with efficient systems and devices to reduce emissions, development and implementation of new types of internal combustion engines, etc. [5, p. 84].

Also, one of the ways to improve the condition of the air basin of urban areas is to increase the share of electric transport in public transport or the introduction of environmentally friendly modes of transport. Such projects are already being implemented in Lutsk, in particular, since December 2020, two environmentally friendly buses operating on gas-fired internal combustion engines have been operating.

In addition, one of the measures to improve the condition of the air can be the introduction of «green» logistics in road and rail transport in the Volyn region. Such ecologically oriented logistics aims to minimize chemical and noise pollution of the atmosphere by optimizing passenger and freight traffic using environmentally friendly or least environmentally hazardous vehicles [11, p. 53]. Based on the above, in our opinion, the most effective measures to reduce

emissions from stationary and mobile sources of pollution and improve air quality in the largest cities of Volyn region are:

- reconstruction and modernization of gas cleaning systems and dust collectors of individual enterprises;
- strengthening control over emissions of impurities into the atmosphere by individual organizations;
- centralization of heating and liquidation of small boilers;
- increasing the share of electric and environmentally friendly public transport in cities;
- increase of the territories of the cities occupied under perennial green plantings;
- introduction of «green» logistics.

Conclusions. Thus, the largest amount of pollutants in the atmosphere of Lutsk, Kovel, Volodymyr-Volynskyi and Novovolynsk is produced by road transport – 85-95 % of all emissions. Stationary sources of pollution produce an average of 12 tons of emissions per 1 km² of urban area. In the cities of Lutsk and Volodymyr-Volynskyi during 2015-2020 there is a decrease in emissions from stationary sources, and in Kovel and Novovolynsk pollution volumes have a slight tendency to increase.

The most of the concentration of impurities is observed in Lutsk, and the indices of air pollution in the city (API₅ and CIAP) correspond to the class «contaminated». The main air pollutant in the city is transport (92-95 % of all emissions). Among the stationary sources of pollution, the largest are: utility company «Lutskteplo» (26 % of point source emissions), Lutskiy remontnyi zavod «Motor» (16 %) and SKF Ukraine Plant (14 %). The most polluted areas

are the Vynnychenko St., Volia Ave., Peremohy Ave., Vidrozhennia Ave., Kovelska St., Rivnenska St., etc.

The consequences of air pollution are manifested in all spheres of life, especially dangerous air pollution is for humans life and health, as it does provoke the development of respiratory and cardio-

vascular disease and cancer. Therefore, the necessary measures to improve the condition of the air are the modernization of treatment plants for air pollutants; reduction of car emissions through the use of environmentally friendly vehicles and the introduction of «green» logistics.

Bibliography

1. Боярин М. В. Вплив метеорологічних умов на рівень забруднення атмосфери ландшафтів Волинської області [Текст] / М. В. Боярин, І. М. Нетробчук, В. У. Волошин // Вісник ХНУ імені В. Н. Каразіна серія «Екологія». – 2016. – Вип. 15. – С. 58-66. [Електронний ресурс]. – Режим доступу: http://journals.uran.ua/visnukhnu_ecology/article/view/90393
2. Гулай Л. Д. Екологічна оцінка стану атмосферного повітря у м. Нововолинськ [Текст] / Л. Д. Гулай, О. А. Караїм, А. Ю. Синюк // Вісник ХНУ імені В. Н. Каразіна. Серія «Екологія». – 2016. – Вип. 14. – С. 58-65. [Електронний ресурс]. – Режим доступу: <https://periodicals.karazin.ua/ecology/article/view/6337>
3. Закон України «Про охорону атмосферного повітря». [Електронний ресурс]. – Режим доступу: <https://zakon.rada.gov.ua/laws/show/2707-12#Text>
4. Кіптенко Є. М. Розроблення схеми короткотермінового прогнозу забруднення повітря для міста Луцьк [Текст] / Є. М. Кіптенко, Т. В. Козленко // Наукові праці УкрНДГМІ. – 2007. – Вип. 256. – С. 318-330. [Електронний ресурс]. – Режим доступу: https://uhmi.org.ua/pub/np/256/5_Kiptenko_Kozl.pdf
5. Книш Ю. В. Шляхи зменшення шкідливих викидів автотранспорту у навколишнє середовище [Текст] / Ю. В. Книш, М. Л. Копій // Науковий вісник НЛТУ України. – 2014. – Вип. 24.3. – С. 81-86. [Електронний ресурс]. – Режим доступу: https://nv.nltu.edu.ua/Archive/2014/24_3/81_Kny.pdf
6. Козубенко Ю. Л. Сучасні реалії забруднення атмосфери в Україні та світі / Ю. Л. Козубенко // Молодий вчений. – 2016. – № 9.1(36.1). – С. 87-90. [Електронний ресурс]. – Режим доступу: <http://molodyvchenny.in.ua/files/journal/2016/9/22.pdf>
7. Мольчак Я. О. Луцьк: сучасний екологічний стан та проблеми [Текст] / Я. О. Мольчак, В. О. Фесюк, О. Ф. Картава. – Луцьк: РВВ ЛДТУ, 2003. – 488 с.
8. Павловська Т. С. Географія Волинської області: навч. посібник [Текст] / Т. С. Павловська. – Луцьк: Вежа-Друк, 2019. – 212 с.
9. Панасюк М. В. Екологічний стан атмосферного повітря Ковельського району Волинської області на основі статистичних даних [Текст] / М. В. Панасюк, Л. Д. Гулай // Вісник ЛДУ БЖД. – 2015. – № 12. – С. 152-156. [Електронний ресурс]. – Режим доступу: https://ldubgd.edu.ua/sites/default/files/3_nauka/visnyky/visnyk/12/12_22.pdf
10. Плахотній С. А. Удосконалення системи управління екологічною безпекою атмосферного повітря та гідрогеологічного середовища навколо вугільних шахт: автореф. дис. канд. тех. наук [Текст] / С. А. Плахотній. Київ, 2017. – 21.
11. Поручинська І. В. Передумови впровадження «зеленої» логістики на автомобільному транспорті Волинської області [Текст] / І. В. Поручинська // Молодий вчений: соціальні комунікації. – 2017. – № 3(43). – С. 53-56. [Електронний ресурс]. – Режим доступу: http://molodyvchenny.in.ua/files/journal/2017/3_43_2017.pdf
12. Регіональна доповідь про стан навколишнього середовища в Волинській області за 2020 рік. [Електронний ресурс]. – Режим доступу: <https://voladm.gov.ua/article/regionalna-dopovid-pro-stan-dovkillya/>
13. Регіональна доповідь про стан навколишнього середовища в Волинській області за 2017 рік. [Електронний ресурс]. – Режим доступу: <https://voladm.gov.ua/article/regionalna-dopovid-pro-stan-dovkillya/>
14. Смирнова С. М. Забруднення атмосферного повітря транспортними засобами м. Миколаєва / С. М. Смирнова, В. М. Смирнов, О. О. Шаповалов // Науковий вісник МДУ імені В. О. Сухомлинського. Біологічні науки. – 2014. – Вип. 6.2(107). – С. 64-70. [Електронний ресурс]. – Режим доступу: http://mdu.edu.ua/wp-content/uploads/files/15_13.pdf
15. Статистичний щорічник Волинь 2020 [Текст] / за ред. В. Науменка. – Луцьк: Головне управління статистики у Волинській області, 2021. – 419 с.
16. Тарасова В. В. Вплив забруднення атмосферного повітря на стан здоров'я населення / В. В. Тарасова // Агросвіт. – 2013. – № 16. – С. 24-28. [Електронний ресурс]. – Режим доступу: http://www.agrosvit.info/pdf/16_2013/6.pdf
17. Chen S. Impact of air pollution on labor productivity: Evidence from prison factory data [Text] / S. Chen, D. Zhang // China Economic Quarterly International. – 2021. – Vol. 1. – Pp. 148-159. <https://doi.org/10.1016/j.ceqi.2021.04.004>
18. Lozano-Sabido E. D., ST-elevation myocardial infarction associated with air pollution levels in Mexico City [Text] / E. D. Lozano-Sabido, E. A. Berrios-Barcenas, A. C. Cazares-Diazleal, E. Viveros-Renteria, J. B. Alvarez-Mosquera, J. M. Portos-Silva, C. R. Kiamco-Castillo // IJC Heart & Vasculature. – 2021. – Vol. 35. – 100846-100854. <https://doi.org/10.1016/j.ijcha.2021.100846>
19. State Statistic Service of Ukraine: Air emissions total and carbon dioxide emissions (1990-2019). [Electronic resource]. – Retrieved from <http://www.ukrstat.gov.ua/>
20. World health organization. Air Pollution. [Electronic resource]. – Retrieved from: <http://www.who.int/airpollution/en/>

Author Contributions: All authors have contributed equally to this work

References

1. Boiaryn, M. V., Netrobchuk, I. M., & Voloshyn, V. U. (2016). Vplyv meteorologichnykh umov na riven zabrudnennia atmosfery landshaftiv Volynskoi oblasti [Influence of meteorological terms on contamination level atmosphere of landscapes Volyn region]. *Visnyk KhNU imeni V. N. Karazina serii «Ekolohiia»*, (15), 58-66. Retrieved from <http://journals.urau.ua/visnyk/ekology/article/view/90393> [in Ukrainian].
2. Hulai, L. D., Karaim, O. A., & Syniuk, A. Yu. (2016). Ekolohichna otsinka stanu atmosfery u m. Novovolynsk [Ecological assessment of atmospheric air in Novovolynsk]. *Visnyk KhNU imeni V. N. Karazina. Serii «Ekolohiia»*, (14), 58-65. Retrieved from <https://periodicals.karazin.ua/ecology/article/view/6337> [in Ukrainian].
3. Zakon Ukrainy «Pro okhoronu atmosfery» [Law of Ukraine «On protection of atmospheric air»]. Retrieved from <https://zakon.rada.gov.ua/laws/show/2707-12#Text> [in Ukrainian].
4. Kiptenko, Ye. M., & Kozlenko, T. V. (2007). Rozroblennia skhemy korotkotermynovoho prohnozu zabrudnennia povitria dlia mista Lutsk [Development of a scheme of short-term forecast of air pollution for the Lutsk City]. *Naukovi pratsi UkrNDHMI*, (256), 318-330. Retrieved from https://uhmi.org.ua/pub/np/256/5_Kiptenko_Kozl.pdf [in Ukrainian].
5. Knysh, Yu. V., & Kopyi, M. L. (2014). Shliakhy zmenshennia shkidlyvykh vykydiv avtotransportu u navkolyshnie seredovyshche [Some ways to reduce harmful automobile emissions into the environment]. *Naukovi visnyk NLTU Ukrainy*, (24.3), 81-86. Retrieved from https://nv.nltu.edu.ua/Archive/2014/24_3/81_Kny.pdf [in Ukrainian].
6. Kozubenko, Y. L. (2016). Suchasni realii zabrudnennia atmosfery v Ukraini ta sviti [Modern realities of air pollution I Ukraine and in the world]. *Young Scientist*, 9.1(36.1), 87-90. Retrieved from <http://molodyvcheny.in.ua/files/journal/2016/9/22.pdf> [in Ukrainian].
7. Molchak, Ya. O., Fesiuk, V. O., & Kartava, O. F. (2003). Lutsk: suchasnyi ekolohichni stan ta problemy [Lutsk: modern ecological state and problems]. Lutsk: RVV LDTU. [in Ukrainian].
8. Pavlovska, T. S. (2019). Heohrafiia Volynskoi oblasti: navch. posibnyk [Geography of the Volyn region]. Lutsk: Vezha-Druk. [in Ukrainian].
9. Panasiuk, M. V., & Hulai, L. D. (2015). Ekolohichni stan atmosfery Kovelskoho raionu Volynskoi oblasti na osnovi statystychnykh danykh [The ecological analysis of air in Kovel district of the Volyn region based on statistical data]. *Visnyk LDU BZhD*, 12, 152-156. Retrieved from https://ldubgd.edu.ua/sites/default/files/3_nauka/visnyky/visnyk/12/12_22.pdf [in Ukrainian].
10. Plahotnii, S. A. (2017). Udoskonalennia systemy upravlinnia ekolohichnoiu bezpekoiu atmosfery ta hidroheolohichnoho seredovyshcha navkolo vuhilnykh shakht [Improvement of the ecological safety management system of the hydrogeological and atmospheric environment around coal mines] (Extended abstract of Candidate's thesis). Kyiv. [in Ukrainian].
11. Poruchynska, I. V. (2017). Peredumovy vprovadzhennia «zelenoi» lohistyky na avtomobilnomu transporti Volynskoi oblasti [Pre-conditions of introduction of «green» logistic are on motor and railway transport of Volyn region]. *Molodyi vchenyi: sotsialni komunikatsii*, 3(43), 53-56. Retrieved from http://molodyvcheny.in.ua/files/journal/2017/3_43_2017.pdf [in Ukrainian].
12. Rehionalna dopovid pro stan navkolyshnoho seredovyshcha v Volynskii oblasti za 2020 rik [Regional report on the state of the environment in the Volyn region in 2020]. Retrieved from <https://voladm.gov.ua/article/regionalna-dopovid-pro-stan-dovkillya/> [in Ukrainian].
13. Rehionalna dopovid pro stan navkolyshnoho seredovyshcha v Volynskii oblasti za 2017 rik [Regional report on the state of the environment in the Volyn region in 2017]. Retrieved from <https://voladm.gov.ua/article/regionalna-dopovid-pro-stan-dovkillya/> [in Ukrainian].
14. Smirnova, S. M., Smirnov, V. N., & Shapovalov, O. O. (2014). Zabrudnennia atmosfery transportnymy zasobamy m. Mykolaieva [Atmospheric air pollution from transport of Mykolaiv]. *Zabrudnennia atmosfery povitria transportnymy Naukovi visnyk MDU imeni V. O. Sukhomlynskoho. Biolohichni nauky*, (107), 64-70. Retrieved from http://mdu.edu.ua/wp-content/uploads/files/15_13.pdf [in Ukrainian].
15. Naumenko, V. (Ed.). (2021). Statystychnyi shchorichnyk Volyn 2020 [Statistical Yearbook of Volyn 2020]. Lutsk: Holovne upravlinnia statystyky u Volynskii oblasti. [in Ukrainian].
16. Tarasova, V. V. (2013). Vplyv zabrudnennia atmosfery na stan zdorovia naseleння [The impact of air pollution on the health of the population]. *Ahrosvit*, 16, 24-28. Retrieved from http://www.agrosvit.info/pdf/16_2013/6.pdf [in Ukrainian].
17. Chen, S., & Zhang, D. (2021). Impact of air pollution on labor productivity: Evidence from prison factory data. *China Economic Quarterly International*, 1, 148-159. [in English]. <https://doi.org/10.1016/j.ceqi.2021.04.004>
18. Lozano-Sabido E. D., Berrios-Barcenas, E. A., Cazares-Diazleal, A. C., Viveros-Renteria, E., Alvarez-Mosquera, J. B., Portos-Silva, J. M., & Kiamco-Castillo C. R. (2021). ST-elevation myocardial infarction associated with air pollution levels in Mexico City. *IJC Heart & Vasculature*, 35, 100846-100854. <https://doi.org/10.1016/j.ijcha.2021.100846>
19. State Statistic Service of Ukraine: Air emissions total and carbon dioxide emissions (1990-2019). Retrieved from <http://www.ukrstat.gov.ua/>
20. World health organization. Air Pollution. Retrieved from: <http://www.who.int/airpollution/en/>

Забруднення атмосферного повітря найбільших міст Волинської області: передумови, наслідки та шляхи вирішення проблеми

Михайло Михайлович Мельничук¹,

к. геогр. н., доцент, кафедра фізичної географії,

¹Волинський національний університет імені Лесі Українки, вул. Потапова, 9, м. Луцьк, 43025, Україна;

Вікторія Віталіївна Горбач¹,

магістр кафедри фізичної географії;

Людмила Миколаївна Горбач²,

к. економ. н., доцент, директор ²Волинського інституту імені В'ячеслава Липинського

ПрАТ «ВНЗ «МАУП», вул. Коперника, 8, м. Луцьк, 43025, Україна;

Олександр Павлович Вовк¹,

к. геол. н., доцент, кафедра фізичної географії

Стаття присвячена дослідженню проблеми забруднення атмосферного повітря найбільш урбанізованих територій Волинської області: м. Луцьк, м. Ковель, м. Нововолинськ та м. Володимир-Волинський. Проаналізовано природні та соціально-економічні умови досліджуваних населених пунктів, що впливають на особливості поширення та розсіювання забруднюючих речовин у просторі. Зокрема, охарактеризовано фізико-географічні особливості розміщення міст (орографію, особливості циркуляції атмосфери тощо), чисельність та густоту їхнього населення, наявність та специфіку промислових виробництв тощо. Виявлено основні стаціонарні та пересувні джерела забруднення повітря, склад та обсяги викидів, їхню просторову та часову динаміку. Встановлено, що основним джерелом забруднення атмосферного повітря у розглянутих містах є автомобільний транспорт, на який припадає 85-95 % усіх викидів. З'ясовано, що динаміка викидів забруднюючих речовин із стаціонарних джерел забруднення протягом останніх п'яти років у м. Луцьк та м. Володимир-Волинський мають загальну тенденцію до зниження. У м. Ковель та м. Нововолинськ спостерігається незначне зростання обсягів викидів. За даними моніторингу на трьох стаціонарних пунктах спостереження, досліджено стан повітряного басейну адміністративного центра області – м. Луцьк, виявлено, що найбільш забрудненим є південно-східний промисловий район міста. Розраховано індекс забруднення атмосферного повітря м. Луцьк окремими компонентами та комплексний індекс забруднення та встановлено, що атмосферне повітря найбільшого міста Волинської області – Луцьк належить до класу «забруднене». З'ясовано, що внаслідок карантинних обмежень, протягом 2020 р у м. Луцьк спостерігався найнижчий показник індексу забруднення атмосфери за останні шість років. Окрім того, у статті висвітлено вплив забруднення атмосферного повітря на навколишнє природне середовище, життя і господарську діяльність мешканців міст Волинської області. Запропоновані заходи покращення стану атмосферного повітря досліджуваних урбосистем, що полягають у скороченні обсягів викидів за рахунок модернізації очисних споруд на підприємствах, використання екологічно-чистих видів транспорту та впровадження «зеленої» логістики.

Ключові слова: забруднення атмосфери, забруднюючі речовини, урбанізовані території, джерела забруднення атмосфери, індекс забруднення атмосфери, специфічно міські хвороби.

Внесок авторів: всі автори зробили рівний внесок у цю роботу

Надійшла 23 жовтня 2021 р.

Прийнята 8 січня 2022 р.