UDK 311.21:[330.34+332.142.6]:303.722.2:[502.3:504.5](477-21)
JEL Classification: C13, O13, Q53, Q57 **Doi: 10.31767/ su.2(97)2022.02.02**

T. V. Kobylynska,
DSc in Economics, Professor of the Department,
Zhytomyr Polytechnic State University,
E-mail: kebpua_ktv@ztu.edu.ua
ResearcherID: N-2678-2018,
ORCID: http://orcid.org/0000-0001-8376-9656;
O. M. Motuzka,
PhD in Economics, Associate Professor,
Associate Professor of Department,
National Academy of Statistics, Accounting and Audit,
E-mail: ommotuzka@nasoa.edu.ua
Researcher ID: K-6501-2018,
ORCID: https://orcid.org/0000-0001-9028-6994

An Assessment of the Environmental-Economic Development of Urbanized Areas in Ukraine

The effective organic development of urbanized areas is a component determining high quality of the population's life and related activities. The ongoing change in the environmental performance necessitates the making of a new roadmap for transformation and urbanization with consideration to tendencies and patterns of environmental phenomena.

An overall assessment of the environmental-economic performance in urbanized areas is a rather complicated issue as it covers many dimensions that cannot be determined by one indicator. It is, therefore, obvious that it should be a set of indicators measuring the relationship between the phenomena occurring due to the environmental change.

The main indicators of environmental friendliness of urbanized areas include ambient air quality, generation and treatment of waste of all the hazard categories, and wastewater treatment. Analysis of the structure and dynamics of these indicators as the main indicators of the environmental performance of urbanized areas is, therefore, critically important.

The article's objective is to determine a set of indicators of the environmental friendliness of cities, explore their relationship, analyze and evaluate the mode of factor effects for the phenomena.

The existing estimates of socio-economic development of cities do not provide the complete coverage of environmental indicators or do not include them at all. This, in particular, refers to the methods for assessment of territorial development in Ukraine (monitoring of regional development indicators).

All the calculations required for the analysis were made using STATISTICA software, "Principal components" method, "Factor analysis" module. The graphic criterion "Screeplot" was used to visualize identification of the components.

Using the Kaiser rule (eigenvalue (λ_j>1) allowed to identify three principal components attributable to 86.6% of the emissions of pollutants generated by stationary sources in urbanized areas of Ukraine.

As shown by the research results, the heaviest polluters among the urbanized areas in 2020 were the cities of Dnipro with 31,100 tons and Kyiv with 25,500 tons. The analyzed tendencies give evidence of a positive move towards improvement in the air basin in the urbanized areas, although the problem of setting pollution margins required for environmental assessment for purposes of international comparisons is yet to be solved.

As the environment preservation has become a challenge of today, issues of waste generation and treatment need to be assigned priority status in creating long-term, medium-term and short-term programs for development of urbanized areas.

Key words: *urbanized areas, statistical assessment, principal component analysis, stationary pollution sources, ambient air, emissions of pollutants.*

Introduction. The current development of urbanized areas at global and national level has a complex character. By now, the process of territorial urbanization has involved the environmental factor encompassing a wide range of problems.

Modern studies and statistical assessments of environmental-economic processes provide sufficient scopes of information allowing to determine environmental effects of territorial urbanization.

It was in 2008 that the data provided by the Population Division of the UN Department of

Economic and Social Affairs (DESA) showed for the first time that more than the half of the world population lived on urbanized areas, and this share continued growing [10; 11]. Three thirds of the urban population across the world are residents of countries with low or medium income. According to UN projections, the growth in the global population expected till 2025 will be contributed by urban centers, thus making the environmental-economic assessment of urbanized areas an issue of critical importance.

Planning and optimization of urban environmental infrastructures has rapidly become a part of both the urban planning theory and the policy for support to improvements of the urban environment, such as urban sprawl control or adaptation to climate change [3; 6]. The relationship between urbanization and climate change has important implications for the ecological sustainability [12].

The growth of cities is accompanied by specific environmental problems, such as waste management or waste water discharges. Large cities concentrate the demand for environmental services and nature resources (water, food and biomass), energy and electricity, with many urban businesses relying on infrastructures and supply chains that can be disrupted by climate change [10].

The article's objective is to determine a set of indicators of the environmental friendliness of cities, explore their relationship, analyze and evaluate the mode of factor effects for the phenomena.

Literature review. A city is characterized by the diversity of interests and continuous activities of various stakeholders. The city development can be defined as changes in the economy, ecosystem and spatial location, resulting from conscious and purposeful activities to achieve the city development goals. The effective and organic development of urbanized areas is a component in achieving high quality of life activities of their inhabitants. The changing natural environment necessitates creating a new roadmap for transformations and urbanization with consideration to tendencies and patterns of the phenomena that require a detailed study, in particular the one based on statistical methods.

As various dimensions of the urbanized life – environmental, economic, social and cultural – are causally related, the successful development of urban areas cannot be achieved unless the comprehensive approach is used. The effective urban management requires allocations of funds for rehabilitation, associated with specific purposes like education, economic growth, social integration and environmental protection. Besides that, it is necessary to establish strong partnerships between local communities, civil society, business and public administration officials of all the levels.

This is critically important given the challenges faced by cities: ageing of the population, economic stagnation in terms of new jobs and social progress, and the implications of climate change. The successful response on these challenges will only be able through determining the ways for meaningful and sustainable growth [2].

Economic tools can push up implementation of environmentally desirable decisions by use of business processes or households. The subsidy system has to be assigned the great importance in this group of tools. It consists of the strategies and "operative programs" administered by the central power offices (industry programs and functional coordination of the whole system) and the strategies and regional operative programs run by regional public administration offices. The other economic tools include the traditional tax and privileges on the property tax that is a local tax imposed on buildings and land.

The tax size is fixed by the city council in keeping with the legally established quotas. The central government is allowed to impose tax privileges on the income tax and establish the zone of privileged tax status, which has great impact on the economic development of adjoining areas. The investment tools, which are mostly government investment, are intended to satisfy social needs, but also have substantial effects for the investment behavior of various actors outside the government sector.

The scope of comprehensive actions for the sustainable development of urban areas must be based on the following key components:

– environmental protection, by purpose: protection of resources, setting the balance between the available resources and the expected level of development, finding solutions for trans-border and interregional problems related with water resources, support of biodiversity, preservation of natural structures, promotion of energy efficiency, stimulation of good energy management and renewed energy sources, limitations on transport intensiveness to reduce emissions of pollutants and greenhouse gases;

– economic development, by purpose: stimulation of growth, adaptation of growth patterns to the territorial specifics, creation of cooperation networks and clusters;

– social challenges, by purpose: reduction of social exclusion tendencies, addressing unemployment and social problems [1].

The environmental components of the system are analyzed by two conceptual approaches: (i) chains of synchronous investigations of main environmental problems that accompany economic development, with consideration for respective environmental risks; (ii) analysis of environmentally focused regulatory measures [4].

The selection of industry categories and indicators for monitoring of the urban sustainability should follow evidence-based and practically acceptable criteria.

The selection procedure should be based on analysis of various requirements and broad recommendations of specialists involved in assessments of the urban environmental sustainability.

Methodological issues to be solved are as follows:

1) criteria for selection of industry categories and indicators;

2) feasible/optimal indicators within thematic categories;

3) stakeholders' contributions in creating structures (selection of thematic categories, goals and indicators);

4) structure and content of methodological indicators;

5) methodology for estimation of the totals and interpretation of the indicators.

The most widely used indicators representing the main thematic categories of a selected framework are determined in [5]. Two key indicators were determined in almost each selected category (except for categories of climate change, education, culture, urban planning and management (one indicator), and mobility and transport (three indicators)).

Constructing indicators set measuring the correlation between the environmental effects of urbanization components. A comparative analysis of the statistical assessment methods leads to the conclusion that an important task is to construct a set of indicators of the environmental friendliness of cities, to explore their correlations, and to analyze and assess the mechanisms of factor effects for the phenomena. Now there is no agreement regarding the methods for constructing a set of indicators measuring the environmental pollution of cities and their environmental friendliness. In the existing methods for assessment of the city development, the indicators of environmental performance are included partially or not found at all. This can be, in particular, referred to the methods for assessment of the spatial development in Ukraine (monitoring of the regional development indicators).

When making a statistical assessment, it needs to be remembered that the overall assessment of the environmental-economic performance of urbanized areas is a complicated exercise because it covers many factors that cannot be measured by one indicator. It is, therefore, obvious that this has to be a set of indicators measuring the correlation between the environmental effects of urbanization components.

Main indicators of the environmental friendliness of urbanized area sare quality of ambient air, waste generation and treatment of all the types of hazardous waste and waste water treatment. An analysis of the structure and dynamics of the above indicators as the main indicators of the environmental performance of urbanized areas is, therefore, critically important.

These indicators pertain to the processes of environmental protection in cities, they are its factors and results directly correlating with each other, as the more measures are taken, the better environmental performance will be in cities.

Gross emission of pollutants and waste generation is activity-specific due to the specificity of emission and waste generation components and their environmental effects resulting from various factors and hidden root causes that create correlations.

The principal component analysis was used to find the correlations between the factors of pollution of urbanized areas and their meaningful interpretation, and to model a set of causal factors [13].

This method is used on the assumption that attributes x_i, being only indicators of certain actual features of a phenomenon, are not subject to direct measurement. This method's essence is in replacing a numerical set x_i with the minimal quantity of maximally informative components G_j.

The main problems dealt withby the principle component analysis are as follows:

– identify G_j component;

– determine the level of G_j for individual units of a statistical population [13].

Because the components are hypothetic values, they can be measured only indirectly, by use of special models.

The correlation between primary attributes and components is expressed in the linear combination:

$$z_i = \sum_{1}^{m} a_j G_j , \qquad (1)$$

where z_i – standardized values of *i* attribute with unit variances; the total variance equals the number of attributes *m*; a_{ij} – factor loading of *j* component on i attribute.

In the process of component analysis, the total variance of *m* primary attributes of x_i is redistributed between the components G_j with variances λ_j. The total variance of a set of attributes *x* can be presented as the total variance of components G_j:

$$m = \sum_{1}^{m} \lambda_j = \sum_{1}^{m} \sum_{1}^{m} a_{ij}^2 . \qquad (2)$$

The principal components are the ones for which, according to Kaiser criterion $\lambda_j > 1$, the factorization completeness is not less than 70%.

The following attributes x_i (i=1 – a) characterizing the environmental effects from stationary pollution sources in urbanized areas were selected for the principal component analysis:

– gross emission of sulfur dioxide (x_1);

– gross emission of nitrogen dioxide (x_2);

– gross emission of carbon oxide(x_3);

– gross emission of methane (x_4);

– gross emission of non-methane volatile organic compounds (x_5);

– capital investment and current expenses on preventing ambient air pollution through modifying production processes or replacing raw materials (x_6);

– capital investment and current expenses on cleaning and increasing the dispersion of smoke and exhaust gases, ventilation emissions (x_7);

– capital investment and current expenses on monitoring and laboratory research for the purpose: protection of ambient air, prevention of climate change and protection of ozone layer (x_8);

– capital investment and current expenses on obtaining permission documents and other measures for the purpose: protection of ambient air, prevention of climate change and protection of ozone layer (x_9).

The reason behind the choice of this set of variables is their ability to give the best characterization of the impact on the emission of pollutants and the economic condition of the stationary pollution sources.

All the necessary computations were made in Statistica software, “Principal components” method, “Factor analysis” module. The graphical criterion “scree plot” was used for the visual assessment of the identification of principal components.

Using the Kaiser rule (eigenvalue (λ_j>1) allowed to identify two principal components that determined the level of pollution in Ukraine, and to estimate the factor loadings of principal components.

Assessment. A key indicator showing the demographic loading on urbanized areas is the population density per 1 km^2 of urbanized areas. Our estimations show that the densest population is in Odesa (6243.6 inhabitants per 1 km^2), Lutsk (5174.2), and Kherson (4773.6).

Changing production scopes and technologies inside and outside the cities change the emissions of hazardous substances in the ambient air, including greenhouse gases. Studies of these processes’ dynamics are important and necessary, because in times of economic transformations users require quick and reliable information on environmental effects from operation of all the industries, including data on the scopes of greenhouse gas emissions in the ambient air. This necessitates a comprehensive analysis of gross emissions of pollutants in the ambient air, which will allow us to make a multidimensional assessment of the ambient air condition and greenhouse gas emissions that provoke the greenhouse effect on the planet.

The dynamics of emissions in the ambient air are measured by the indicator of gross emissions of hazardous substances, which is significantly important in monitoring the risk of climate change.

This indicat or was estimated by data from the following sources:

– aggregated data on gross emissions of pollutants in the ambient air from stationary pollution sources, based on the official statistical observation “Protection of ambient air” [7];

– estimated data on gross emissions of hazardous substances from mobile pollution sources [9];

– data on inventories of greenhouse gas emissions [8].

The main environmental effect from the development pressure is emissions of pollutants resulting in the pollution of the ambient air, which is the main proxy of the quality and expectancy of life, especially in urbanized areas.

The dynamics of main indicators of the development pressure show a reduction in gross emissions of pollutants in urbanized areas.

Throughout 2020, the air basin of Ukrainian cities was affected by 537.500 tons of all the types of pollutants (Table 1).

Table 1

Emissions of pollutants in urbanized areas of Ukraine, 1991–2020

(thousand tons)

Year	Overall emissions of pollutants	Including:			
		sulfur dioxide	nitrogen dioxide	methane	carbon oxide
1991	1880.5	384.5	197.4	18.3	748.5
2001	1153.0	110.5	64.3	18.2	418.4
2011	1339.8	128.4	74.7	21.1	486.1
2017	587.6	99.4	58.1	33.9	308.8
2018	581.3	131.8	56.3	30.8	338.5
2019	569.7	61.7	47.3	28.6	284.5

The annual discharge of pollutants in the ambient air of urbanized cities is nearly 1 million tons, with the average emission density per urbanized city making 121.3 tons.

The estimations for 1991–2020 show that while the emissions of sulfur dioxide from stationary pollution sources in urbanized areas reduced by 75.3%, the emissions of methane grew by 1.6%. The emissions of methane grew by 82.5% in 2017 against 1991, but the emissions of nitrogen dioxide reduced by 70.6%.

The dynamics of these indicators are illustrated by estimating chain growth rates.

The results of estimations show that the largest polluters among the urbanized areas in 2020 were the cities of Dnipro with 31,100 tons, and Kyiv with 25,500tons.

Our analysis demonstrates a positive tendency: the ambient air in the urbanized areas did improve, although the problem of fixing pollution margins required in environmental assessments for purposes of international comparisons is yet to be solved.

As environmental protection is a challenge of today, issues of waste generation and treatment have to be the priority ones in elaborating long-, medium- and short-term development programs for urbanized areas. In times of the pandemic caused by COVID-19, the public concern needs to be focused on utilization of municipal, household and plastic waste generated in private households.

Our study involved a correlation analysis that gave evidence of the multicollinearity between the indicators: x_3 and x_7 (0.987), x_5 and x_9 (0.926), x_8 and x_9 (0.868) in 2020. To avoid the multicollinearity and make a regression analysis, we proposed to determine the main factors of the existing nine: the emission of pollutants from the economic activities of stationary pollution sources (Table 2).

Table 2

The characteristic attributes of the emission of pollutants in the ambient air of urbanized areas, x_i

	Y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
Y	1,000	0,659	0,723	0,995	0,204	0,021	–0,027	0,987	0,115	0,126
x_1	0,659	1,000	0,723	0,599	0,110	0,217	–0,021	0,613	0,200	0,203
x_2	0,723	0,723	1,000	0,655	0,416	0,423	–0,013	0,689	0,501	0,537
x_3	0,995	0,599	0,655	1,000	0,160	–0,047	–0,032	0,987	0,056	0,060
x_4	0,204	0,110	0,416	0,160	1,000	0,710	–0,095	0,167	0,556	0,781
x_5	0,021	0,217	0,423	–0,047	0,710	1,000	0,248	0,002	0,787	0,926
x_6	–0,027	–0,021	–0,013	–0,032	–0,095	0,248	1,000	0,036	0,359	0,092
x_7	0,987	0,613	0,689	0,987	0,167	0,002	0,036	1,000	0,180	0,121
x_8	0,115	0,200	0,501	0,056	0,556	0,787	0,359	0,180	1,000	0,868
x_9	0,126	0,203	0,537	0,060	0,781	0,926	0,092	0,121	0,868	1,000

All the required computations for the analysis were made in the STATISTICA software, "Principal components" method, "Factor analysis" module. The graphical criterion "scree plot" was used for the visual assessment of the identification of principal components. Using the Kaiser rule (eigenvalue (λ_j > 1) allowed to identify three principal components attributable to 86.6% of the emissions of pollutants generated by stationary sources in urbanized areas of Ukraine.

The factor loading in the group has to be higher than the normative margin of 0.70 [5]. Data in Table show that the contributions of the first, second and third components in the total variance of the feature set are 45.9%, 28.3% and 12.4%, respectively. In overall, the components are attributable to nearly 86.6% of the total variance, thus confirming the high level of factorization (Table 3).

Table 3

The factor loadings of principal components

Variable	Factor 1, F_1	Factor 2, F_2	Factor 3, F_3
x_1	–0.593	–0.547	–0.038
x_2	–0.844	–0.360	0.049
x_3	–0.528	–0.791	–0.029
x_4	–0.710	0.358	0.391
x_5	–0.767	0.567	–0.015
x_6	–0.148	0.210	–0.941
x_7	–0.586	–0.748	–0.102
x_8	–0.786	0.441	–0.224
x_9	–0.843	0.495	0.125

To simplify interpretation of the components and redistribute the variation with preserving the total variance of the determined components, we used the convolution "varimax normalized", on the condition that the factor loading in the group must be higher than the normative margin of 0.70 (Table 4).

Table 4

Results of factor loadings after the "varimax normalized" procedure

Variable	F_1	F_2	F_3
x_1	0.140	0.795	0.008
x_2	0.464	0.793	–0.028
x_3	–0.054	0.949	–0.043
x_4	0.836	0.120	–0.269
x_5	0.940	0.016	0.167
x_6	0.090	–0.014	0.971
x_7	0.006	0.955	0.040
x_8	0.846	0.141	0.356
x_9	0.979	0.109	0.025

So, the contributions of the first, second and third components in the total variance of the feature set are 38.9%, 34.7% and 13%, respectively. In overall, the three components are attributable to 86.6% of the total variance, thus confirming the high level of factorization.

The first factor including the variables x_4, x_5, x_8 and x_9 can be interpreted as capital investment aimed at protecting the ozone layer.

The second factor that also included four variables, x_1, x_2, x_3 and x_7, can be interpreted as hazardous emissions of the third class of danger.

The third component is loaded by one variable, capital investment and current expenses for preventing pollution of the ambient air through modifying production processes. This factor can, therefore, be interpreted as the production modification.

The principal component analysis also allows to estimate the three determined factors for each Ukrainian city (Table 5). Signs (positive or negative) with each component value show each factor's level in each city: to what extent it is higher (+) or lower (–) than the average [4].

Table 5

Values of principal components in urbanized areas of Ukraine

City	F_1	F_2	F_3
1	2	3	4
Vinnytsia	–0.136	–0.394	–0.31
Lutsk	–0.451	–0.364	–0.34
Dnipro	0.320	0.977	–0.19
Mariupol	–0.384	4.209	–0.58
Zhytomyr	–0.374	–0.338	–0.32
Uzhhorod	–0.506	–0.378	–0.36
Zaporizhzhia	0.653	0.906	2.32
Ivano-Frankivsk	–0.482	–0.372	–0.38
Kropivnytskyi	–0.223	–0.389	–0.28
Lviv	–0.199	–0.328	–0.21
Mykolaiv	–0.272	–0.354	0.74
Odesa	0.132	–0.387	–0.73
Poltava	–0.290	–0.386	–0.33
Rivne	–0.397	–0.315	–0.37
Sumy	–0.221	–0.218	2.37
Ternopil	–0.490	–0.371	–0.36
Kharkiv	–0.052	–0.346	2.53
Kherson	0.200	–0.443	–1.02

Table 5, continued

1	2	3	4
Khmelnytskyi	–0.444	–0.371	–0.34
Cherkasy	–0.181	0.427	–0.44
Chernivtsi	–0.406	–0.379	–0.29
Chernihiv	–0.190	–0.188	–0.61
Kyiv	4.392	–0.198	–0.50

So, the first factor has the highest level in Dnipro, Zaporizhzhia, Odesa, Kherson and Kyiv, which is attributable to the high extent of urbanization and pollution of these cities.

The second factor characterizing hazardous substances of the third class of danger has higher than the average effect in Dnipro, Mariupol, Zaporizhzhia and Cherkasy.

The third factor pertaining to the production modification was higher than the average in Zaporizhzhia, Mykolaiv, Sumy and Kharkiv, which can be considered as a positive trend and a high level of the production modification.

At the second phase, the impact of each of the three factors on the scopes of emissions from stationary pollution sources in urbanized cities of Ukraine was estimated by the multiple regression (Table 6).

Table 6

Estimates of factor impact on the scopes of emissions from stationary pollution sources in urbanized cities of Ukraine

City	Emissions, Y	F_1	F_2	F_3
Vinnytsia	2.7	–0.136	–0.394	–0.31
Lutsk	0.7	–0.451	–0.364	–0.34
Dnipro	31.1	0.320	0.977	–0.19
Mariupol	339.4	–0.384	4.209	–0.58
Zhytomyr	1.6	–0.374	–0.338	–0.32
Uzhhorod	0.1	–0.506	–0.378	–0.36
Zaporizhzhia	64.7	0.653	0.906	2.32
Ivano-Frankivsk	0.4	–0.482	–0.372	–0.38
Kropivnytskyi	2.2	–0.223	–0.389	–0.28
Lviv	2.8	–0.199	–0.328	–0.21
Mykolaiv	3	–0.272	–0.354	0.74
Odesa	2.5	0.132	–0.387	–0.73
Poltava	0.9	–0.290	–0.386	–0.33
Rivne	3.7	–0.397	–0.315	–0.37
Sumy	6.9	–0.221	–0.218	2.37
Ternopil	0.4	–0.490	–0.371	–0.36
Kharkiv	3.7	–0.052	–0.346	2.53
Kherson	4.7	0.200	–0.443	–1.02
Khmelnytskyi	0.9	–0.444	–0.371	–0.34
Cherkasy	18.9	–0.181	0.427	–0.44
Chernivtsi	0.7	–0.406	–0.379	–0.29
Chernihiv	7	–0.190	–0.188	–0.61
Kyiv	25.5	4.392	–0.198	–0.50

So, the estimated regression coefficients allowed to build an equation of the dependence of the emission of pollutants from stationary pollution sources under the impact of the determined factors and effects of correlation of the second factor with the other factors:

$$Y = 22.8 - 16.5\,F_1 + 49.7\,F_2 + 6.5\,F_3 - 95.9\,F_2 \cdot F_1 + 22.5\,F_2 \cdot F_3. \qquad (3)$$

The estimated regression coefficients allowed to build an equation of the dependence of the emission of pollutants from stationary pollution sources on the determined factors and effects of correlation of the second factor with the other factors.

Conclusions. As first factor (capital investment aimed at protecting the ozone layer) increases, the average emissions from stationary sources will decrease by 16.500 tons; as the second factor (hazardous substances of the third class of danger) increases, the average emissions from stationary sources will grow by nearly 50,000 tons; the impact of the third factor (production modification) causes the average growth in the emissions from stationary sources by 6,500 tons; the correlation of the first and second factors will cause the average reduction of the emissions by 95,900 tons; and the correlation of the second and third factors will cause the average growth in the emissions from stationary sources by 22,500 tons. It is determined by the value of beta coefficients that the largest impact is produced by the second factor (0.97), the correlation of first and second factors (–0.88), and the first factor (Table 7).

Table 7

Results of a regression analysis of the impact of determined factors

Constant term, factors	Beta coefficients	Regression coefficients	*t*-criterion	Significance level
a_0	–	22.8043	13.33655	0.000000
F_1	–0.803325	–16.4685	–5.56166	0.000034
F_2	0.974179	49.7236	17.79030	0.000000
F_3	0.609698	6.5812	3.17152	0.005579
$F_2 \cdot F_1$	–0.886562	–95.9163	–7.90167	0.000000
$F_2 \cdot F_3$	0.730905	22.4544	4.41566	0.000378

The multiple regression coefficient is 0.989. It shows that 98.9% of the total variation of the effective feature is attributable to the variation of the three determined factors. The estimated level of significance α=0.000000<0.05, which confirm the significance of R^2. Testing of the model for adequacy by Fisher's ratio test and the graphic form of regression residuals confirmed its significance.

To overcome the negative trends of pollution in urbanized areas, it is necessary to implement a targeted state environmental policy. Further author's research will be devoted to the search for effective tools for the implementation of such a policy.

References

1. Borsa, M. (2015). Polityka przestrzenna w Polsce w latach 2004–2013 [Spatial policy in Poland 2004–2013]. *Wybrane regionalne I lokalne polityki publiczne w Polsce – 10 latdoświadczeń w warunkach członkostwa w Unii Europejskiej*. Z. Strzelecki (Ed.) Ministerstwo Infrastruktury i Rozwoju. (p. 41–66). Warszawa [in Polish].

2. Borsa, M., Baczyński, K., Brodowicz, D., & Godlewski, J. (2016). *Ecology Constructively*. Sustainable_ Development_of_Urban_Areas. M. Szabłowski (Ed.). Siedlce: Collegium Mazovia Innowacyjna Szkoła Wyższa. Retrieved from https://www.researchgate.net/publication/305636672_ECOLOGY_ CONSTRUCTIVELY_-_Sustainable_Development_of_Urban_Areas

3. Gavrilidis, A. A., Niță, M. R., Onose, D. A., Badiu, D. L., & Năstase, I. I. (2019). Methodological framework for urban sprawl control through sustainable planning of urban green infrastructure. *Ecological indicators, 96,* 2, 67–78. Retrieved from https://doi.org/10.1016/j.ecolind.2017.10.054

4. Lopatynskyi, Y., & Meglei, V. (2018). Ekologiczny I ekonomiczny rozwój rolnictwa na Ukrainie [The ecological and economic development of agriculture in Ukraine]. *Gospodarka w Praktycei Teorii, 53 (4),* 95–109. Retrieved from https://doi.org/10.18778/1429-3730.53.06 [in Polish].

5. Michalina, D., Mederly, P., Diefenbacher, H., & Held, B. (2021). Sustainable Urban Development: A Review of Urban Sustainability Indicator Frameworks. *Sustainability, 13,* 9348. Retrieved from https://doi.org/10.3390/su13169348

6. Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning, 134,* 127–138. Retrieved from https://doi.org/10.1016/ j.landurbplan.2014.10.018

7. State Statistics Committee of Ukraine. (2019). Metodolohichni polozhennia z orhanizatsii derzhavnoho statystychnoho sposterezhennia shchodo vykydiv zabrudniuiuchykh rechovyn vid peresuvnykh dzherel

zabrudnennia [Methodological guidelines on organization of the official statistical observation on emission of polluting substances from mobile pollution sources]. Kyiv. *ukrstat.gov.ua*. Retrieved from http://ukrstat.gov.ua/metod_polog/metod_doc/2019/395/395.pdf [in Ukrainian].

8. State Statistics Committee of Ukraine. (2019). Metodolohichni polozhennia z orhanizatsii derzhavnoho statystychnoho sposterezhennia shchodo vykydiv zabrudniuiuchykh rechovyn ta parnykovykh haziv v atmosferne povitria vid statsionarnykh dzherel zabrudnennia [Methodological guidelines on organization of the official statistical observation on emission of polluting substances and greenhouse gases in the ambient air from stationary pollution sources]. Kyiv. *ukrstat.gov.ua*. Retrieved from http://www.ukrstat.gov.ua/norm_doc/2019/454/454.pdf [in Ukrainian].

9. State Statistics Committee of Ukraine. (2020). Metodolohichni polozhennia zi skladannia rakhunku vykydiv v atmosferu [Methodological guidelines on compilation of the account of emissions in the ambient air]. Kyiv. *ukrstat.gov.ua*. Retrieved from http://www.ukrstat.gov.ua/norm_doc/2020/268/268.pdf [in Ukrainian].

10. UN. DESA. (2018). *2018 Revision of World Urbanization Prospects*. Retrieved from https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

11. UNISDR (2013). Global Assessment Report on Disaster Risk Reduction 2013. *From Shared Risk to Shared Value: The Business Case for Disaster Risk Reduction*. Geneva: United Nations Office for Disaster Reduction. Retrieved June 17, 2022 from https://www.preventionweb.net/english/hyogo/gar/2013/en/home/GAR_2013/GAR_2013_3.html

12. Wilbanks, T. J., & Kates, R. W. (2010). Beyond adapting to climate change: embedding adaptation in responses to multiple threats and stresses. *Annals of the Association of American Geographers, 100 (4)*, 719–728.

13. Yerina, A. M. (2001). *Statystychne modeliuvannia ta prohnozuvannia [Statistical modelling and forecasting]*. Kyiv: Kyiv National Economic University named after Vadym Hetman [in Ukrainian].

Т. В. Кобилинська,
доктор економічних наук,
професор кафедри,
Державний університет "Житомирська політехніка",
E-mail: kebpua_ktv@ztu.edu.ua
ResearcherID: N-2678-2018,
ORCID: http://orcid.org/0000-0001-8376-9656;
О. М. Мотузка,
кандидат економічних наук, доцент,
доцент кафедри,
Національна академія статистики, обліку та аудиту,
E-mail: ommotuzka@nasoa.edu.ua
ResearcherID: K-6501-2018,
ORCID: https://orcid.org/0000-0001-9028-6994

Оцінка еколого-економічного розвитку урбанізованих територій в Україні

Ефективний органічний розвиток урбанізованих територій є одним із елементів забезпечення високої якості життєдіяльності населення. Зміни, які відбуваються в навколишньому природному середовищі, приводять до формування нової дорожньої карти трансформації та урбанізації з урахуванням тенденцій і закономірностей розвитку явищ.

Загальна оцінка еколого-економічного стану урбанізованих територій є досить складною, адже охоплює багато напрямів, які неможливо визначити одним показником. Тому очевидно, що це має бути система індикаторів, яка відображає зв'язок між напрямами, зумовленими впливом навколишнього природного середовища.

Основними показниками екологічності урбанізованих територій є якість атмосферного повітря, утворення та поводження з відходами усіх класів небезпеки й очищення стічних вод. Отже, аналіз структури та динаміки вищезазначених показників як основних індикаторів екологічного стану урбанізованих територій є вкрай актуальним.

Усі необхідні розрахунки для аналізу проведено з використанням системи STATISTICA, метода Principal components, модуля Factor analysis. Для візуальної оцінки виокремлення головних компонент використано графічний критерій "кам'янистий спад" (Scree plot). За правилом Кайзера (власні числа ($\lambda_j > 1$) виділено три головні компоненти, що пояснюють 86,6% формування викидів забруднюючих ре-

човин від стаціонарних джерел в урбанізованих територіях України. Результати дослідження свідчать, що найбільшими забруднювачами серед урбанізованих територій у 2020 році були м. Дніпро (31,1 тис. т) та м. Київ (25,5 тис. т). Спостерігається позитивна тенденція до покращення повітряного басейну урбанізованих територій, проте залишається до кінця невирішеним питання встановлення порогових рівнів забруднення, що необхідно для проведення екологічної оцінки для міжнародних порівнянь.

Однією з проблем сьогодення є збереження довкілля, тому питання утворення відходів та поводження з ними мають бути в пріоритеті при формування довгострокових, середньострокових та короткострокових програм розвитку урбанізованих територій

Ключові слова: *урбанізовані території, статистична оцінка, аналіз головних компонент, стаціонарні джерела забруднення, атмосферне повітря, викиди забруднюючих речовин.*

Bibliographic description for quoting:

Kobylynska, T. V., & Motuzka, O. M. (2022). An Assessment of the Environmental-Economic Development of Urbanized Areas in Ukraine. *Statystyka Ukrainy – Statistics of Ukraine, 2,* 12–21. Doi: 10.31767/su.2(97)2022.02.02 [in Ukrainian].

Бібліографічний опис для цитування:

Кобилинська Т. В., Мотузка О. М. Оцінка еколого-економічного розвитку урбанізованих територій в Україні (публікується англійською мовою). *Статистика України*. 2022. № 2. С. 12–21. Doi: 10.31767/su.2(97)2022.02.02