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Assessment of Waste Treatment in Urbanized Areas in the Environmental Policy Context: National Experience

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Abstract

The environmental challenges of today worsen the life conditions and create threats for a human. An issue of special concern in the environmental security context are urbanized areas characterized by heavy environmental pollution. Analysis of the impact of waste generation and treatment in Ukraine on the environmental performance of urbanized areas and its conformity with the principles for decision-making on setting priorities and strategies on the basis of comparable information has significant importance in elaborating urgent measures for environmental stabilization in urbanized areas.

Principal component analysis was used for estimating the correlations between the factors of pollution in urbanized areas, their meaningful interpretation and modeling of the complex factor impact. The factors were selected, characterizing the environmental effects, which is waste generation from economic activities of stationary pollution sources in urbanized areas: burnt waste of all the hazard categories; total accumulated waste per 1 square km; capital investment and current expenses on treatment of waste of I–III hazard categories; capital investment and current expenses on treatment of waste of IV hazard category; capital investment and current expenses on waste disposal in specially designated places or waste objects of waste of IV hazard category; capital investment and current expenses on monitoring and laboratory tests for the objective: waste treatment (except for radioactive waste).

The results of assessment confirmed the impact of these factors on the environmental performance of Ukrainian cities.

Keywords: pollution, environmental friendliness indicators, sustainability of cities, urbanized areas, waste generation.

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1. Introduction

A problem of primary importance at country and planetary scale is environment preservation, reduction of greenhouse gas emission, recycling of waste generated by business activities.

The inadequate level of information support and lack of firmly established law will inevitably suppress the motivation of business entities and private households to environmental activities.

The current research effort and evaluation of environmental economic processes is able of providing sufficient information allowing to determine environmental effects from economic activities in urbanized areas (Decrees of SSSU, 2017, 2020).

The current environmental performance of urbanized areas at global and national level have a complex nature. Nowadays, the process of spatial urbanization involves the environmental factor combining a wide range of problems.

It was in 2008 that data of the United Nations Department of Economic and Social Affairs (DESA) showed that more than half of the global population had lived on urbanized areas, and that this share was continuously growing (UN DESA, 2012). And each one of the four city inhabitants in the world lives in countries with low or medium income. Because UN predictions demonstrate that nearly all the population increase till 2050 will be contributed by city centers, environmental economic assessment of urbanized areas should be a topical and critically important field of research.

Planning and optimization of urban environmental infrastructures has been quickly becoming an integral part of both the theory of urban planning and the policy for improvement of the urban environment, which example is control over urban sprawl (Gavrilidis et al., 2019) or adaptation to climate change (Norton et al., 2015). The relationship between urbanization and climate change has important implications for the environmental sustainability (Wilbanks and Kates, 2010).

The growth of cities entails specific environmental problems like waste management or management of waste-water discharges. Large cities concentrate the demand and need in environmental services and nature resources (water, foods and biomass), energy and electricity, thus making many city companies rely on infrastructures and supply chains that can be broken by climate change (UNISDR, 2013).

2. Literature review

The considerable contribution in addressing theoretical and methodological issues related with assessment of pollution effects for the environmental economic performance at country level was made by domestic and foreign researchers B. Danylyshyn, S. Dorohuntsov, V. Tretiak, M. Khvesyk and others. V. Mishchenko, Yu. Makovetska and T. Omelianenko analyzed the institutional aspects of waste treatment in Ukraine on its way to the European integration (Mishchenko et al., 2013).

The development of cities can be defined as change in economy, ecosystem or spatial location, caused by conscious and purposeful activities to achieve the city development goals. The effective organic development of urbanized areas is a component contributing to the high quality of life activities of city residents.

Various dimensions of the urbanized life – environmental, economic, social – are interlinked, and the successful development of urbanized areas can only be achieved using the comprehensive approach. The effective urban environmental management requires allocated funds for rehabilitation, which need to be linked with funds for education, economic growth and environmental protection.

Besides that, it is necessary to set up strong partnership with urban communities, civil society, business and administrative power officials of all the levels.

It is critically important in view of the challenges faced by cities, such as ageing of the population, economic stagnation hampering creation of new jobs and social progress, and the consequences of climate change. The effective response on these challenges will not be feasible unless the ways of reasonable and sustainable growth are determined (Borsa et al., 2016) .

Economic instruments stimulate the implementation of environmentally desirable decisions through business processes or households. The great importance in this group of instruments is assigned to the subsidy system. It consists of the strategies and "operative programs" administered by central power bodies (industry programs and functional coordination of the whole system) and the strategies and regional operative programs supervised by regional power bodies.

The scope of comprehensive actions for the sustainable development of urban areas needs to be based on several critical issues:

- environmental protection, with the objectives: resource protection, keeping the balance between the available resources and the planned level of development, finding cross-border and cross-regional solutions for problems related with water resources, support to biodiversity, preservation of natural structures, promotion of energy efficiency, encouragement of reasonable management of energy and renewable energy sources, limitations of transport intensity to reduce the emission of pollutants and greenhouse gases;
- economic development, with the objectives: stimulation of the growth, bringing the growth trends in conformity with the specifics of a given area, creation of cooperation networks and clusters;
- social challenges, with the objectives: reduction of social exclusion trends, unemployment combat and finding solutions for social problems (Borsa, 2015).

Environmental components of the system should be analyzed by two conceptual approaches: first, the synchronic analysis of main environmental problems involved in the economic development, with consideration to the respective environmental risks; second, the analysis of environmentally focused measures of government regulation (Lopatynskyi et al., 2018).

The monitoring of sustainability of cities constitute a problem in selecting relevant industry categories and indicators. This process requires the selection of criteria based on scientific evidence and practical implementation.

This procedure should be based on analysis of various requirements, general recommendations of the authors engaged in the assessment of environmental sustainability at city level.

Michalina et al. (2021) determined the most commonly used indicators representing the main thematic categories of the selected framework. Two key indicators were determined in each selected category (except for the categories of climate change, education, culture, urban planning and management (one indicator), mobility and transport (three indicators)).

3. Problem setting

It should be noted that problems of methodology construction in the environmental field, especially generation, storage and recycling of waste, still remain unsolved. Seeking for their solutions has the increasing importance for the national policy of Ukraine, for the development of research theory and practice, because of their great impact on the quality of information support for decision-making at all the levels.

4. The article objective

The article's objective is to assess the impact of waste generation and treatment in Ukraine on the environmental performance of urbanized areas and the conformity of the assessment method with the principles of decision-making in setting priorities and strategies in this field.

5. Research methodology and methods

A comparative analysis of the assessment methodologies leads to the conclusion that an important problem is to determine a set of indicators of environmental friendliness of cities, investigate their relationship, and assess the mechanisms of the factors' impact on the phenomena. By now, there have been no standard methods for constructing a set of indicators measuring the environmental pollution of cities by waste and environmental friendliness of cities. In the existing sets of socio-economic development indicators at city level, the environmental performance indicators are either limited in terms of coverage or missing at all. This is the case of methodologies for the assessment of spatial development in Ukraine (monitoring of development indicators at regional level).

When making the assessment, it is necessary to bear in mind that the overall estimate of environmental economic performance of urbanized areas is composite one, because is includes many dimensions that cannot be determined by one indicator. It is, therefore, obvious that it needs to be a set of indicators reflecting the relationship between the dimensions.

A key indicator of the environmental friendliness of urbanized areas is generation and treatment of hazardous waste with all the hazard categories. An analysis of dynamics and structure of the above mentioned indicators as the main indicators of the environmental performance in urbanized areas is, therefore, critically important.

Being closely related with the processes involved in protecting the city environment, these indicators are its factors and results with the direct correlation: the more measures are taken, the better is the environmental performance.

Waste generation is activity-specific due to the specificity of 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 (Yerina, 2001).

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 with by the principle component analysis are as follows:

- identify G_j component;
- determine the level of G_j for individual units of a statistical population (Yerina, 2001).

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:

$$z_{i=} \sum_1^m a_{ij}\, Gj, \qquad (1)$$

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:

$$\mathrm{m} = \sum_1^m \lambda_j = \sum_1^m \sum_1^m a_{ij}^2 \qquad (2)$$

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

In view of the above, the following attributes x_i *(i=1-a)*characterizing the environmental effects, including waste generation from economic activities of stationary pollution sources in urbanized areas, were selected for the principal component analysis in modelling:

- ✓ burnt waste of all the hazard categories (x_1);
- ✓ total waste accumulated during the exploitation in special sites or objects of all hazard categories (x_2);
- ✓ total accumulated waste per 1 square km (x_3);
- ✓ total accumulated waste per 1 person (x_4);
- ✓ capital investment and current expenses on collection and transportation of waste of all the hazard categories (x_5);
- ✓ capital investment and current expenses on treatment of waste of I–III hazard categories (x_6);
- ✓ capital investment and current expenses on treatment of waste of IV hazard category (x_7);
- ✓ capital investment and current expenses on waste disposal in specially designated places or waste objects for waste of IV hazard category (x_8);
- ✓ capital investment and current expenses on monitoring and laboratory tests for the objective: waste treatment (except for radioactive waste) (x_9);
- ✓ capital investment and current expenses on obtaining permits and other activities for the objective: waste treatment (except for radioactive waste) (x_{10}).

The reason behind the choice of this set of variables is their ability to give the best characterization of the impact on the scopes of generated waste, and to characterize the condition of 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.

So, two principal components could be selected using Kaiser rule (eigenvalues ($\lambda j>1$), which determined the pollution level in Ukraine, with estimating factor loadings of principal components.

5. Research results

The factors with impact on the waste generation in urbanized areas of Ukraine were determined by correlation and regression analysis (see Table 1).

Table 1
Results of the regression analysis of the impact of selected factors on the scopes of waste generation

	Beta coefficients	Regression coefficients	t-criterion	Significance levels
a_0		131.312	1.764	0.098
x_1	0.394	7.249	1.661	0.117
x_3	0.616	0.001	3.026	0.009
x_6	-0.141	-0.012	-0.551	0.590
x_7	0.991	0.018	28.534	0.000
x_8	-0.842	-0.027	-6.053	0.000
x_9	0.831	2.330	5.788	0.000

Source: the author’s estimations

Six indicators were selected of the abovementioned ten:

- ➢ burnt waste of all the hazard categories (x_1);
- ➢ total accumulated waste per 1 square km (x_3);
- ➢ capital investment and current expenses on treatment of waste of I–III hazard categories (x_6);
- ➢ capital investment and current expenses on treatment of waste of IV hazard category (x_7);
- ➢ capital investment and current expenses on waste disposal in specially designated places or waste objects of waste of IV hazard category (x_8);
- ➢ capital investment and current expenses on monitoring and laboratory tests for the objective: waste treatment (except for radioactive waste) (x_9).

Considering that our objective is to analyze the impact of factors x_1 (burnt waste), x_3 (total accumulated waste per 1 square km, because the analysis is focused in Urbanized areas of Ukraine) and x_6 (capital investment and current expenses on treatment of waste of I–III hazard categories), the multiple regression was used for estimating the impact of each factor and building the regression for all the six factors (see Table 1).

The estimated regression coefficients enabled for constructing an equation of the dependence of the waste generation under the impact of the selected factors:

$$Y=131{,}3+7{,}2x_1+0{,}001x_3-0{,}012x_6+0{,}018x_7-0{,}027x_8+2{,}33x_9 \quad (3)$$

The multiple determination coefficient is 0.990. It shows that 99.0% of the overall variation of the effective attribute is explained by the variation of the factors included in the model. It means that the selected factors with impact on the scopes of generated waste confirm the reasonability of their inclusion in the regression model, whereas the remaining 1.0 % is accounted for by the other impact factors. The estimated level of significance α=0.000000<0.05, which confirms the significance of R^2.

So, when the burnt waste of all the hazard categories is increased by 1,000 tons, the total waste generation will increase by 7,200 tons. It shows that burning is not a means of preventing waste generation, but rather a way of combatting waste, which is confirmed by the statistical insignificance of this factor (p=0.117, which is lower than 0.05) that can be excluded from the model. When the waste accumulation per 1 square m increases by 1 ton, the average total waste will increase by 0.001 thousand tons. This factor is statistically significant, and it is important for us only in the context of waste generation outside Ukrainian cities, in regions with high or low industry concentration.

When the capital investment and current expenses on treatment of waste of I–III hazard categories increase by 1,000 UAH, the total waste will reduce by 0.012 thousand tons, which is positive. This factor was found to be statistically insignificant (p=0.59, which is lower than 0.05). But we believe that it is worth to be remained in the model, because its insignificant impact can be attributable to a low share of capital investment aimed at combatting the waste of I–III hazard categories. In the industrial regions of Ukraine accounting for the major share of waste of I–III hazard categories the shares of investment in treatment of waste of I–III hazard categories are as follows: 5.8 % in Dnipro, 0.01%, in Mariupol, 4.6% in Zaporizhzhia, less than 1% in Kyiv. These shares are the largest in Chernivtsi (34 % of the total investment in treatment of all the categories of waste) and Rivne (10 %).

When the capital investment and current expenditure in treatment of waste of IV hazard category is increased by 1,000 UAH, the total waste will increase by 0.018 thousand tons. When the capital investment and current expenditure for waste disposal in specially designated places or objects for waste of IV hazard category increase by 1,000 UAH, the average total waste will reduce by 0.027 thousand tons. This gives evidence that waste disposal can be an effective means of combatting waste generation and accumulation.

When the capital investment and current expenditure for monitoring of waste treatment increase by 1,000 UAH, the average total waste generation will increase by 2.33 thousand tons. It can be assumed that the capital investment in seeking for alternative means was ineffective, or that the share of these investment was small, although the factor in the model was statistically significant.

Results of the analysis allow us to suggest that the capital investment needs to be reallocated with regard to the hazard categories of waste.

The estimated beta coefficients show that the factors with the strongest impact are x_7 (0.991), x_8 (-0.842), and x_9 (0.831).

The Backward Stepwise Regression of Statistica software also allowed to highlight only three statistically significant factors (x_7, x_8, x_9). They are as follows:

- capital investment and current expenses on treatment of waste of IV hazard category (x_7);
- capital investment and current expenses on waste disposal in specially designated places or waste objects of waste of IV hazard category (x_8);
- capital investment and current expenses on monitoring and laboratory tests for the objective: waste treatment (except for radioactive waste) (x_9).

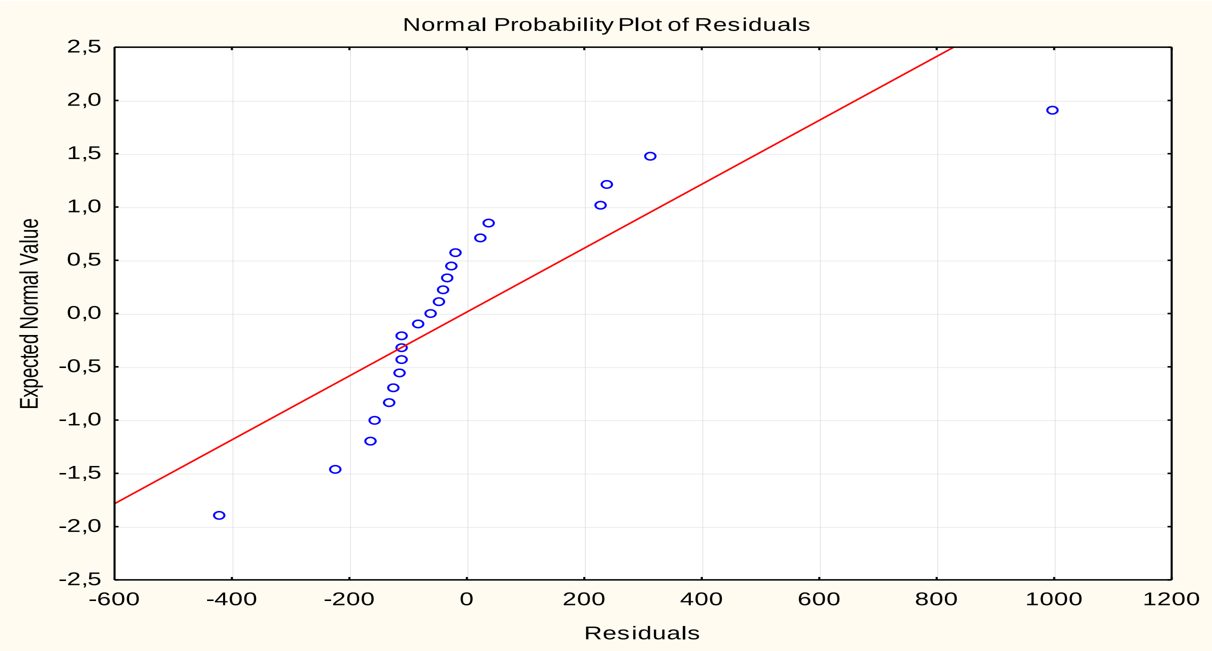
The estimated regression coefficients allowed for constructing an equation of the dependence under the impact of the highlighted factors:

$$Y=209,1++0,018x_7-0,024x_8+2,58x_9 \quad (4)$$

6. Conclusions and research prospects

When the factor 7 (capital investment and current expenses on treatment of waste of IV hazard category) increases, the average waste generation by stationary sources will increase by 0.018 thousand UAH; increase in the factor 8 (capital investment and current expenses on waste disposal in specially designated places or waste objects for waste of IV hazard category) will cause the average reduction in the waste generation by 0.024 thousand UAH; the impact of the factor 9 (capital investment and current expenses on monitoring and laboratory tests for the objective: waste treatment (except for radioactive waste)) will cause the average growth in the waste generation by 2,580 UAH.

The oscillation of points around the curve provides a visual confirmation of the model's applicability. Testing of the model for adequacy (R^2 = 0,99) by Fisher's ratio test (326.25) and the graphic view of the regression model's remainder confirmed its significance (Figure 1).



Source: computed and constructed by the author

Fig. 1. The graphic view of the normal distribution of remainder

So, the principal component analysis allowed to make a statistical assessment of the environmental effects from economic activities of stationary pollution sources in urbanized areas of Ukraine and confirm the impact of selected factors on the environmental performance of Ukrainian cities.

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