Sustainable Development of Territories in the Zone of Industrial Facilities

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Abstract. The article is devoted to the urgent problem of sustainable development of territories in the zone of industrial facilities. The aim of the study is a comprehensive assessment of the environmental sustainability of industrial regions with different levels of population density and the identification of local patterns of the impact of negative factors on the environment. The object of the study in the article is the municipalities of the Republic of Tatarstan in the zone of industrial facilities. As the main research methods, we used the method of one-dimensional scaling or scoring to determine the differentiation of territories according to the level of environmental sustainability, the method of regression analysis to model the sustainable development of industrial regions. The author determined the nature of the interdependence of the environmental sustainability of territories and population density, revealed local patterns determined by the level of industrialization of the regions. The author's method is proposed and a comprehensive assessment of the environmental sustainability of industrial territories is made, including the anthropogenic load, the state of the environment, and the level of public health. Depending on the weight coefficient (population density level), an integral assessment of environmental sustainability is calculated, allowing classification of regions into four levels. The necessity of a differentiated approach to managing the sustainable development of industrial territories, based on the diagnosis of environmental stress parameters and their trends, is substantiated. The results of the study can be used in the development of priorities and environmental documents of industrial enterprises, in the activities of state and municipal governments, including in resolving issues of the national project "Ecology".

Keywords: sustainable development, environmental monitoring, industrial regions, urban agglomerations, anthropogenic pressure, quality of life

1 Introduction

Industrialized regions that are actively introducing new industrial production of various profiles are at risk of destabilization of the ecological system. Today, when designing new industrial facilities and reconstructing existing facilities, insufficient

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attention is paid to assessing the impact of negative factors on the environment and the quality of life of the population.

The development of territories under the negative impact on the environment of industrial enterprises has been the subject of numerous works by foreign and domestic scientists. The main directions of research in the field of the concept and principles of sustainable development of territories are determined by the works of the following scientists: Zhou Y., Kong Y., Sha J. and et al examined the modernization of the industrial structure in the evolution of eco-efficiency in a spatial aspect [1], Gonzalez S., Dias A. studied the integration of life cycle and urban metabolism [2], Fernando L., Suarez M., Eugenia M. proposed a multidisciplinary model for urban sustainability [3], Chertow M., Gordon M., Hirsch P. and et al appreciated the potential of industrial symbiosis and the potential of urban infrastructure in India [4], Le M., Berrah L., Stutz B. and et al. proposed a concept and system model for sustainable development of business parks [5]. The development of urban agglomerations in an environment of environmental imbalance was investigated by Bettigny I., Meireles J., Fernandez G. and et al [6], John B., Luederitz C., Lang D. and et al. [7], Tsui S. [8], Romanova A., Ilina E., Dobroserdova E. and et al. [9].

Contribution to the sustainable development of industrial zones and eco-industrial parks was made by such researchers as Elmassa S. [10], Akansu V., Gertik A. [11], Zheng S., Cui K., Sun S. and et al [12], Yu X., Zheng H., Sun L. and et al [13]. Issues of industrial symbiosis in an urban environment were studied by Marcinkovsky A. [14], Liu Z., Adams M., Wen Z. and et al [15], Shinkevich A., Malysheva T., Ryabinina E. and et al [16], Rajskaya M., Sagdeeva A., Panteleeva Y. and et al [17]. The problems of efficiency, competitiveness and environmental safety of industrial production in Tatarstan are considered in the works Malysheva T., Shinkevich A., Ostanin L. and et al [18], Dyrdonova A., Shinkevich A., Galimulina F. and et al [19], Malysheva T., Shinkevich A., Ostanina S. and et al [20].

However, despite the availability of an extensive theoretical and methodological data set and practical solutions, there is a lack of research to solve the problem of diagnosis and a differentiated approach to managing the development of industrial areas and increasing their environmental sustainability. This leads to the fact that the implementation of a set of issues on the sustainable development of industrial zones is indicative, more subjective and weakly related to the specific structure of the economy of urban agglomerations.

2 Methods

For the purposes of intermediate and integral ecological zoning, the article uses the method of one-dimensional scaling — a point estimate. Using this approach to integrate a system of indicators is due to a large number of environmental sustainability parameters, as well as their variability. The methodology is intended for the classification of territories according to the level of environmental sustainability. The algorithm for calculating the integral indicator of the environmental sustainability of a municipality, based on the determination of intermediate and final point estimates, has the following form:

a) Three categories of industrial regions were accepted as an object of study:

– industrialized urban agglomerations (urban districts);
– regions with industrial enterprises and agricultural organizations in the structure of the economy;
– regions with the main profile of the economy – the agricultural sector.
b) For the indicators of assessment by the links of the environmental sustainability diagnostics chain, the average score varies from 1 to 8, which corresponds to a change in the ecological situation from "relatively satisfactory" to "crisis" (Table 1).

Table 1. Scale for assessing the environmental sustainability of industrial zones

Scoring	Environmental sustainability
$1 < Q_1 < 2$	Satisfactory (Q_1)
$3 < Q_2 < 4$	Stress (Q_2)
$5 < Q_3 < 6$	Critical (Q_3)
$7 < Q_4 < 8$	Crisis (Q_4)

c) The category of regions determines the working interval or scale of values, on the basis of which the absolute value of the indicator is transformed into a relative one - from 1 to 8 points:

$$I = (Xmax – Xmin) / 8, \qquad (1)$$

where I – interval, $Xmax$ – the maximum value of the indicator in the group, $Xmin$ – the minimum value of the indicator in the group.
Ecological zoning is carried out according to the three main elements of environmental sustainability: anthropogenic pressure, the state of the ecosystem, and the health of residents. For the industrial region, for each component of environmental sustainability, taking into account all incoming indicators, the final score for the block is calculated:

$$Bi = Bn / N, \qquad (2)$$

where Bi – final score, Bn – points on indicators of the environmental sustainability system, N – the number of indicators in the block of the environmental sustainability system.
The integrated assessment of the degree of environmental sustainability of an industrial region is calculated by the formula:

$$E_N = \sqrt{B_1 * B_2}, \qquad (3)$$

where E_N – degree of environmental sustainability, B_1 – interim environmental assessment; B_2 – assessment of the population density in the region.
It can be assumed that, ceteris paribus, theoretically more environmentally unstable is the industrial region where there is a relatively high population density. Such environmental monitoring can be used by state authorities, local governments in the development of appropriate decisions in the field of environmental protection, sustainable development of territories.

3 Results and Discussion

The problem of increasing the industrial load on the environment and increasing the number of residents in urban agglomerations requires the development of effective management decisions in terms of minimizing the negative impact on the environment. The anthropogenic load on the ecosystem leads to a deterioration of the biosphere; an increase in production and consumption waste introduces an imbalance in the environment.

As population density increases, the degree of impact on the ecosystem changes. Actively growing urban agglomerations are a key factor in the negative impact on the natural environment. In large municipalities, the main stationary sources of pollution are concentrated – industrial production, as well as mobile pollutants – transport.

Undoubtedly, with the same level of negative impact on the ecosystem, the deterioration in the quality of life will be greater in those areas where there is a higher concentration of the population. The main area of concentration of industrial territories is in the range B_1 = 3-4.4 points и B_2 = 1-6 points (fig. 1). Outside the concentration field (emissions) to the left are large industrial centers with a high population density and a stable environmental situation. To the right are industrially undeveloped areas with a low population density and adverse ecology due to land cultivation by chemicals and pollution of water bodies.
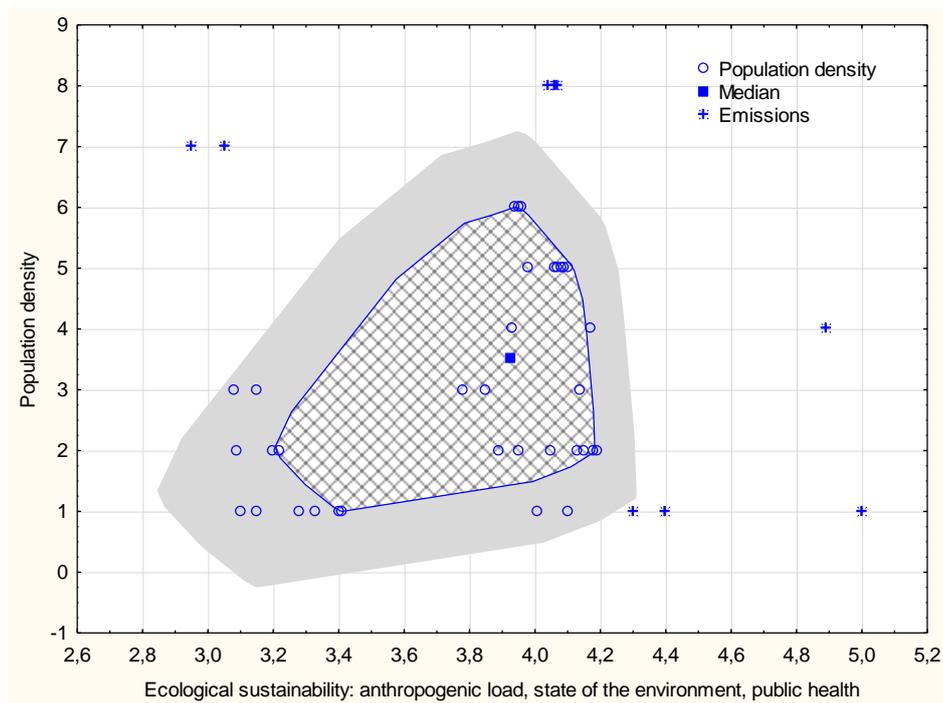
Fig. 1. Concentration Chart "Environmental Sustainability: Anthropogenic Pressure, Environment, Population Health – Population Density"

In Tatarstan, a population density of more than 45 inhabitants per square kilometer is noted in large urban agglomerations – the cities of Kazan, Naberezhnye Chelny, as well as in Almetyevsk, Bugulminsky, Elabuzhsky, Zelenodolsky, Leninogorsk, Mendeleev, Nizhnekamsk, Chistopol municipal areas. The higher the population density of the municipality, the ceteris paribus the lower the degree of environmental sustainability.

Integral assessment of the environmental situation made it possible to classify the industrial and agro-industrial regions of Tatarstan according to the level of environmental sustainability into 3 groups (Table 2).

Table 2. Integral assessment of the state of the ecosystem and classification of the territories of Tatarstan by the level of environmental sustainability

Name of the industrial zone (municipality)	The average score for the blocks: anthropogenic load, state of the environment, public health	Average population density score	Final average environmental sustainability score
Satisfactory situation (1 group, 14 regions)			
Aznakaevsky, Bavlinsky, Buinsky, Zainsky, Leninogorsk, Nurlatsky, Alekseevsky, Rybno-Slobodsky, Spassky, Tetyushsky, Alkeevsky, Verkhneuslonsky, Muslumovsky, Novosheshminsky	3.42	1.21	2.00
Stress situation (2 group, 21 regions)			
Elabuga, Chistopol, Agryz, Apastovsky, Kamsk-Ustinsky, Laishevsky, Mamadyshsky, Menzelinsky, Aktanyshsky, Kaybitsky, Tyulyachinsky, Cheremshansky, Almetyevsky, Bugulminsky, Aksubaevsky, Arsky, Sabinsky, Sarmanovsky, Yutazinsky, Yutazinsky	3.95	3.38	3.43
Crisis situation (3 group, 8 regions)			
Zelenodolsky, Baltasinsky, Kukmorsky, Drozhzhanovsky, Pestrechinsky, Nizhnekamsk, Mendeleev, Vysokogorsky	3.75	7.00	5.37
Critical situation (4 group, 0 regions)			

The distribution of industrial and agro-industrial regions of the Republic of Tatarstan according to the degree of environmental sustainability made it possible to obtain the following groups: group 1 – 14 municipalities with a relatively low degree of environmental sustainability; group 2 – 21 municipalities with an average degree of

environmental sustainability; group 3 – 8 municipalities with a relatively high degree of environmental sustainability.

The relationship of the anthropogenic load on the quality of life of the population, expressed by the health of residents, is investigated by regression analysis. We clarify that the anthropogenic load in this case includes the negative impact of industry (X_1), agriculture (X_2) and automobile transport (X_3). The adequacy of the obtained regression equation is confirmed by the coefficient of determination $Kd = 72\%$ and Student criterion $t > 1$. Thus, the selected variables are nonrandom and the statistics are significant.

The regression model, reflecting the influence of anthropogenic stress factors on the effective sign – the level of public health, has the following form:

$$Y = 3.22 + 0.12_1 + 0.06X_2 + 0.08X_3 \tag{4}$$

where Y – health of residents in the territory of industrial facilities; X_1 – industrial impact; X_2 – agricultural impact; X_3 – impact of transport.

The resulting model allows us to identify the intensity of the relationship, to show how fast the change in independent factors (anthropogenic load indices) affects the change in the health of residents. As the model shows, industry has the biggest impact on the health of the population ($K_1 = 0.12$). Less significant impact of agriculture ($K_2 = 0.06$) and transport ($K_3 = 0.08$).

Table 3 presents the regression models of sustainable development by categories of industrial and agro-industrial zones. Industrialized urban agglomerations are characterized by a more active impact of industry and vehicles. In this regard, the improvement of the quality of life of these territories can occur mainly due to positive changes in the activities of industrial enterprises and the organization of road transport.

Table 3. Regression models of sustainable development of industrial and agro-industrial zones on an administrative basis

Industrial Zone Category	Regression model
1. Industrialized urban agglomerations (urban districts)	$Y_1 = 5.79 + 0.76X_1 - 0.09X_2 + 0.36X_3$
2. Regions with industrial enterprises and agricultural organizations in the structure of the economy	$Y_2 = 3.80 + 0.23X_1 + 0.21X_2 + 0.18X_3$
3. Regions with the main profile of the economy - the agro-industrial complex	$Y_3 = 3.63 - 0.03X_1 + 0.21X_2 + 0.14X_3$

In regions with industrial enterprises and agricultural organizations in the structure of the economy, the effect of anthropogenic stress elements on the level of public health is almost equal. Positive dynamics of the health status of residents will be more likely with an effective environmental policy regarding industrial production, the organization of work in the agricultural sector, as well as a decrease in transport load.

It is logical that in regions with the main profile of the economy - the agro-industrial complex, the prevailing effect on the quality of life of the population is shown by the agricultural factor, whose effect is due to chemical fertilizers that pollute the soil and flow from the fields to water bodies.

The obtained regression models of sustainable development depending on the category of territories make it possible to assess the directions and intensity of development of municipalities under the influence of environmental factors.

4 Conclusions

As a result of the study of the environmental sustainability of the territories in the zone of industrial facilities, the following scientific and practical results were obtained:
1) The high population density of the territories increases the anthropogenic burden on the ecosystem and has a negative impact on the sustainability of the development of the territory. At the same time, as the concentration of the population in the industrial zone increases, ceteris paribus, the degree of environmental sustainability increases, which is due to a higher level of industrialization of the economy, the use of high-tech industrial equipment, and environmental culture.
2) Differentiation of territories according to the level of environmental sustainability made it possible to distinguish three zones: satisfactory, intense, and crisis. A positive factor is the lack of regions in the most unfavorable critical zone. The largest in terms of the number of territories is the group where the tense ecological situation is revealed. With a high degree of probability, we can assume that in the case of positive changes in the environmental situation with sufficient natural and financial resources, the regions of the middle group may enter the first group with a high degree of environmental sustainability or the third group with a low degree of environmental sustainability.
3) Modeling of sustainable development of territories showed the need for a differentiated approach to environmental management in municipalities of various categories. The factors of anthropogenic load (industrial, agricultural, transport) show a different impact on the quality of life of the population of the territories, which is associated with the level of infrastructure development, the quality and priorities of administrative management, and the specific structure of the economy.
The results of the study can be used in the development of priorities and environmental documents of industrial enterprises, in the activities of state and municipal authorities, including in addressing the implementation of the national project "Ecology".

References

1. Zhou Y., Kong Y., Sha J., et al. (2019). The role of industrial structure upgrades in eco-efficiency evolution: Spatial correlation and spillover effects. *Science of the Total Environment*, 687, 1327-1336.
2. Gonzalez S. & Dias A. (2019). Integrating lifecycle assessment and urban metabolism at city level: Comparison between Spanish cities. *Journal of Industrial Ecology*, 23, 5, 1062-1076.

3. Fernando Molina-Prieto L., Suarez-Serrano M. & Eugenia Villa-Camacho M. (2019). Multidisciplinary loop for urban sustainability. *Revista de Arquitectura*, 21, 2, 76-89.

4. Chertow M., Gordon M. & Hirsch P., et al. (2019). Industrial symbiosis potential and urban infrastructure capacity in Mysuru, India. *Environmental research letters*, 14, 7, 075003.

5. Le Tellier M., Berrah L., Stutz B., et al. (2019). Towards sustainable business parks: A literature review and a systemic model. *Journal of Cleaner Production*, 2016, 129-138.

6. Bettignies Y., Meirelles J., Fernandez G., et al. (2019). The Scale-Dependent Behaviour of Cities: A Cross-Cities Multiscale Driver Analysis of Urban Energy Use. *Sustainability,* 11, 12, 3246.

7. John B., Luederitz C., Lang D., et al. (2019). Toward Sustainable Urban Metabolisms. From System Understanding to System Transformation. *Ecological economics*, 157, 402-414.

8. Cui X. (2018). How can cities support sustainability: A bibliometric analysis of urban metabolism. *Ecological indicators*, 93, 704-717.

9. Romanova A.I., Ilina E.V., Dobroserdova E.A., Shindina T.A. & Mironova M.D. (2015). The Movement of Capital in the Field of Information Services. *Journal of Internet Banking and Commerce*, 20, 1, 010.

10. ElMassah S. (2018). Industrial symbiosis within eco-industrial parks: Sustainable development for Borg El-Arab in Egypt. *Business Strategy and the Environment*, 27, 7, 884-892.

11. Akansu V., Gertik A. (2018). The sustainability of unused industrial areas: an example, historical development of the Cyprus copper deposit. *Amazonia Investiga*, 7, 14, 91-103.

12. Zheng S., Cui K., Sun S., et al. (2020). Planning and design based on landsenses ecology: the case study of Chongming Island Landsenses Ecol-industrial Park. *International Journal for Sustainable Development and World Ecology*, Early Access, Feb, 2020.

13. Yu X., Zheng H., Sun L.. et al. (2020). An emissions accounting framework for industrial parks in China. *Journal of Cleaner Production*, 244, 118712.

14. Marcinkowski A. (2019). The Spatial Limits of Environmental Benefit of Industrial Symbiosis - Life Cycle Assessment Study. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 7, 3, 521-538.

15. Liu Z., Adams M., Wen Z., et al. (2019). Review of eco-industrial development around the globe: Recent progress and continuing challenges. *Resources Conservation and Recycling*, 143, 111-113.

16. Shinkevich A.I., Malysheva T.V., Ryabinina E.N., Morozova N.V., Sokolova G.N., Vasileva I.A. & Ishmuradova I.I. (2016). Formation of network model of value added chain based on integration of competitive enterprises in innovation-oriented cross-sectorial clusters. *International Journal of Environmental and Science Education*, 11, 17, 10347-10364.

17. Rajskaya M.V., Sagdeeva A.A., Panteleeva Yu.V., Malysheva T.V. & Ershova I.G. (2019). Differentiated approach problems to innovative development management in russian regions. *Humanities and Social Sciences Reviews,* 7, 4, 1262-1268.

18. Malysheva T.V., Shinkevich A.I., Ostanin L.M., Zhandarova L.F., Muzhzhavleva T.V. & Kandrashina E.A. Organization challenges of competitive petrochemical products production. *Espacios*, 39, 9, 28.

19. Dyrdonova A.N., Shinkevich A.I., Galimulina F.F., Malysheva T.V., Zaraychenko I.A., Petrov V.I. & Shinkevich M.V. (2018). Issues of industrial production environmental safety in modern economy. *Ekoloji*, 27, 106, 193-201.

20. Malysheva, T.V., Shinkevich, A.I., Ostanina, S.S., Vodolazhskaya, E.L. & Moiseyev, V.O. (2016). Perspective directions of improving energy efficiency on the meso and micro levels of the economy. *Journal of Advanced Research in Law and Economics*, 7, 1, 75.