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ECOLOGICAL COMFORT OF THE URBAN ENVIRONMENT ON THE EXAMPLE OF THE CITY OF BARNAUL

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Ensuring a positive human environment is one of the most important urban management tasks, which requires appropriate scientific support. The results of a review of scientific publications of foreign and national publications concerning assessing the quality (comfort) of the living environment allow determining the main factors affecting the quality of life of the urban population. These factors include atmospheric air quality, noise pollution, road network and traffic, the nature of real estate development, and site landscaping. Based on the selected factors, the research objective was to develop a multi-faceted approach to the ecological assessment of the urban environment comfort, which can be applied in practice when planning the development of urban areas. The following indicators were used as assessment indicators: average annual concentration of suspended solids, noise level, intensity of traffic flows, real estate development density, share of green spaces, and area of parks and recreation sites. The studies of the municipal entity territory of the city of Barnaul, Altai Krai, conducted according to the developed methodology made it possible to identify the most ecologically uncomfortable zones of the city and propose approaches to solving the existing ecological problems. The most acute problems of the city urban environment are the non-uniformity of site landscaping, the congestion of highways, and the low level of improvement of the entire territory, especially the recreation areas. These things significantly reduce the

ecological comfort level of the population living. In order to improve it, it is necessary to take real actions to improve urban infrastructure, first of all, to optimize transport flows, expand and create new zones of green spaces.

Keywords: *living environment; ecological comfort; urban environment pollution*

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ЭКОЛОГИЧЕСКИЙ КОМФОРТ ГОРОДСКОЙ СРЕДЫ НА ПРИМЕРЕ ГОРОДА БАРНАУЛА

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Обеспечение положительной среды обитания человека является одной из важнейших задач управления городским хозяйством, решение которой требует соответствующего научного обеспечения. Результаты обзора научных публикаций зарубежных и отечественных изданий по вопросам оценки качества (комфортности) среды обитания позволяют определить основные факторы, влияющие на качество жизни городского населения. К этим факторам относятся качество атмосферного воздуха, шумовое загрязнение, дорожная сеть и трафик, характер застройки и благоустройство территории. На основе выделенных факторов целью исследования являлась разработка комплексного подхода к экологической оценке комфортности городской среды, который может быть применен на практике при планировании развития городских территорий. В качестве индикаторов оценки использовались следующие показатели: среднегодовая концентрация взвешенных веществ, уровень шума, интенсивность транспортных потоков, плотность застройки, доля зеленых насаждений, площадь парков и зон отдыха. Исследования территории города Барнаула, Алтайский край, проведенные по разработанной методике, позволили выявить наиболее экологически неблагополучные зоны города и предложить подходы к решению существующих экологических проблем. Наиболее острыми проблемами городской среды являются неравномерность озеленения территории, загруженность автомобильных дорог, низкий уровень благоустройства всей территории, особенно зон отдыха. Эти проблемы существенно снижают уровень экологической комфортности проживания населения. Для ее улучшения необходимо предпринимать реальные действия

по совершенствованию городской инфраструктуры, в первую очередь, по оптимизации транспортных потоков, расширению и созданию новых зон зеленых насаждений.

Ключевые слова: *среда обитания; экологический комфорт; загрязнение городской среды*

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Introduction

The population concentration in a relatively small space of modern cities leads to a growing conflict between the society and the environment: the quality of the environment is declining, and a social strain is growing. In recent years, there has been a significant increase in publications devoted to the environmental issues of urbanization, which are prominently manifested in North America, Europe, and the Asia-Pacific Region [19]. The task of improving the quality of life and ensuring an ecological comfort of the population is becoming crucial for all big Russian cities, but this problem is especially acute in the eastern part of the country. The peculiarities of Siberia and the Far East development, associated with the development of mineral deposits and the policy of creating and developing an industrial base, ignoring the meeting the population needs, have led to the formation of peculiar features of urbanization. There is an excessive, hypertrophied development of the administrative center against the background of the degradation of the remaining settlements of the region. Although, the intraurban environment is characterized by the following factors: (1) location of industrial enterprises within the city limits; (2) absence of buffer zones between production facilities and residential areas; (3) irrational transportation network when parts of the city isolated from each other are connected by single highways; and (4) unfavorable ratio of residential and industrial zones [3]. The problems that have developed in the process of territory urbanization in the twentieth century are even more increased as a result of the modern, often chaotic development of the urban space without considering environmental factors associated with a reduction in green spaces [20]. These things have led to relatively low quality of the environment of the Siberian cities of Russia. The problem relevance is also determined by the need to ensure human environmental safety in the light of the current climate agenda [1]. A high level of environmental safety creates an opportunity for the harmonious existence and

development of a person in an urban environment as a biological and social organism [5]. The scientific community even developed the idea of creating eco-cities [11; 13; 14] and a portfolio of "green" technologies for urban planning is also forming [2; 17]. The most important criterion for the environment quality is its comfort, which is a subjective perception and an objective state of full health under given conditions of the urban environment surrounding a person, including its natural and socio-economic indicators [9]. The environmental comfort index of the urban environment can be measured and evaluated using remote sensing technologies [15]. Monitoring of urban pollution is an indicator of environmental engineering [3]. Although, by ecological comfort, we mean the optimal combination of natural and anthropogenic environmental factors for the life of the population of the given territory, which ensures comfortable living conditions for each person, as well as the reproduction of labor, intellectual, and human potential of the territory [7].

Materials and methods

This research aims to develop and test a methodology for assessing the ecological comfort of the environment on the example of one of the Russian cities. The research object was the administrative center of Altai Krai – the city of Barnaul.

Ecological comfort acts as a system with many direct and inverse interrelations, including infrastructure, economy, transport, and environmental conditions. The factors affecting the degree of ecological comfort are heterogeneous and diverse, making it difficult to choose a methodology for their assessment. Two big groups of factors – pollution and improvement of the urban environment – were selected to assess the ecological comfort. The results of studying these factors when assessing the comfort and environmental safety of the urban environment are presented in the works of such researchers as S. Yilmaz, E. Mutlu and H. Yilmaz [21], F. Gómez et al. [12], T.-Y. Ling and Y.-C. Chiang [16]. The atmospheric air quality greatly influences the formation of a comfortable environment in the settlement. In accordance with the World Health Organization (WHO) recommendation, the indicator of this factor is the content of finely dispersed suspended particles in the atmospheric air. This indicator was estimated according to the data of the West Siberian Department for Hydrometeorology and Environmental Monitoring, which monitors the state of the air environment and publishes data on the concentration of suspended particles.

Automobile transport is a source of atmospheric air pollution and light, heat, and noise emission. That is why it is necessary to consider such an indicator as the intensity of traffic flows near the places of residence and work of the popu-

lation within the city. The determination of this indicator was conducted on the largest roads in urban areas using visual observations.

Among the improvement factors, the main ones were selected for the research: (1) area of green spaces; (2) urban saturation; and (3) presence of parks and recreation sites. The assessment was performed based on cartographic materials using the tools of the ArcMap set of geospatial programs.

Thus, the assessment of the urban environment ecological comfort in the Barnaul districts was performed based on the following indicators:

- Content of suspended solids in the atmospheric air;
- Noise level;
- Intensity of traffic flows;
- Area of green spaces;
- Urban saturation;
- Area of parks and recreation areas.

Results

The city of Barnaul is a large industrial and administrative center of Russia located in the Siberian Federal District. In terms of population, Barnaul belongs to the category of the largest cities in Russia, as more than 695 thousand people live in it. The settlement annually consumes about 560 thousand tons of natural resources, whereby the total volumes of generated emissions, effluents, and waste exceed 450 thousand tons [6; 8]. There are five districts within the territory of the city – Tsentralny, Leninsky, Zheleznodorozhny, Industrialny, and Oktyabrsky, which widely vary in terms of area, population (Table 1), and environmental comfort level.

Table 1.

Characteristics of the administrative districts of Barnaul

City district	Territory area, km^2	Population size, persons	Population density, persons/km^2
Oktyabrskiy	69.4	99,416	1,432
Leninsky	125.6	144,077	1,147
Industrialny	129.9	186,301	1,434
Zheleznodorozhny	15.0	113,373	7,558
Tsentralny	145	107,466	741

About a third of the Barnaul population lives in the Industrialny District. Population density is the most important ecological factor affecting environmental quality. A high concentration of the population is observed in the

Zheleznodorozhny District, where the population density exceeds 7.5 thousand persons/km^2. The lowest population density is registered in the Tsentralny District (741 persons/km^2).

Cities are characterized by a high level of a natural environment transformation leading to a change in chemical indicators. The level of atmospheric air pollution in the city of Barnaul has been assessed as high for many years. As a result of the activity of large industrial enterprises in the heat-power engineering, mechanical engineering, petrochemical and food industries, more than 50 thousand tons of pollutants are discharged into the atmosphere of the city annually. Automobile transport has become a serious pollution source in recent years. The number of cars in the city increased to 264 thousand, and the volume of emissions from mobile sources exceeded 46.5 thousand tons. As a result of the ingress of such a quantity of emissions, the content of benzpyrene (benzopyrene), suspended solids, nitrogen dioxide, formaldehyde, and carbonic oxide in the air has long exceeded the permissible level. Exceeding the Maximum Permissible Concentrations (MPC) regarding suspended solids (dust) during the year is noted in all city districts, while the average annual concentration of the ingredient is about 2 MPC. The maximum concentrations of suspended solids in the air are observed in the Tsentralny and Oktyabrsky Districts, where the permissible standards are 3–4 times exceeded due to soil dust in the summer [4].

The anthropogenic activity also changes the physical characteristics of the environment, among which noise emission is of the greatest importance. The conducted studies have revealed an increased noise level in the Tsentralny and Industrialny Districts. In the vicinity of the main city highways, the equivalent sound level can reach 78–82 dBA during the day and up to 70–100 m at width on adjacent road shoulders, noise – 50–77 dBA [4].

The intensity of traffic flows is another important factor affecting the level of living ecological comfort in an urban environment. A significant proportion of multi-story residential buildings are located near large multi-lane highways. The intensity of traffic flows affects the noise pollution level, atmospheric air quality, and light pollution at nighttime. Large highways, running across thickly settled microdistricts, do not meet modern transport infrastructure standards and cannot provide reliable protection of the population living nearby from exhaust gases and noise in most cases [10]. According to the data obtained, the intensity of traffic flows in the Industrialny District considerably exceeds the indicators of the other city districts being analyzed (Table 2).

The adverse influence of the polluted environment could be significantly reduced by large areas occupied by woody vegetation. The existing provision

of green spaces for general usage is sufficiently high and exceeds the town planning rules per capita in Barnaul, but they are spread extremely nonuniformly. Tree and shrubbery plantings occupy large areas in the Tsentralny District (Table 2), in which the share of green spaces in general usage exceeds 8% of the total area. The area of green spaces in the Zheleznodorozhny District is extremely small. Here, this indicator is only 1.4%. This is due to a high degree of anthropogenic transformation of the territory. The territory is distinguished by a high degree of development (more than 46%) and the concentration of the main transportation routes of the city, both highway and main railway lines.

Table 2.

Environment ecological comfort indicators of the administrative districts of the city of Barnaul

City district	Environment pollution			Site improvement		
	Atmospheric pollution level	Average noise level (dB)	Traffic flow intensity (car/hour)	Green space area, %	Development density, %	Recreation parks area, ha
Oktyabrsky	High	61.6	1,737	7.95	22.3	41.7
Leninsky	Elevated	68.8	2,748	2.51	11.3	63.8
Industrialny	High	71.5	4,419	3.61	19.2	5
Zheleznodorozhny	Elevated	67.3	3,047	1.38	46.4	0
Tsentralny	High	73.1	2,956	8.37	9.4	29

The conducted research allowed us to compile a generalized description of the urban environment in the context of administrative districts, presented in Table 2. The most comfortable living environment is noted in the Leninsky and Oktyabrsky Districts of the city per totality of factors. This is due to the fact that these areas are characterized by vast areas of green spaces, including parks and natural vegetation, lower indicators of development density and the intensity of traffic flows, and a lower number of stories. The impact of traffic and noise pollution on the population is lower in these areas since a residential sector is often located at a greater distance from the roadway than in other city areas.

The least comfortable area is the Zheleznodorozhny District. The area has a very high development density combined with a small green area. There are large highways with a high traffic capacity. This fact causes significant air pollution from mobile sources, including noise pollution. There are a critically small amount of green spaces here, and there are no forest and parkland zones.

Discussion

Papers concerning a comprehensive assessment of the urban environment ecological state of Barnaul were first fulfilled in the early 2000s. I.D. Rybkina [8] notes in her paper that a critical ecological situation is observed in almost all city districts. The main causes of environmental problems are the territorial proximity of industrial zones to residential development quarters, the absence of sanitary protection zones for enterprises, and the general lack of urban area development. In the author's opinion, the most favorable situation has developed in the Tsentralny District of Barnaul, which is associated with the high ability of natural complexes to self-purification and an insignificant concentration of industry [8].

Our studies show that significant changes have taken place since then. On the one hand, the economic downfall and the closure of a number of businesses reduced the anthropogenic load on the environment, and on the other hand, there was an increase in the number of cars and the intensity of traffic flows. Moreover, the development of the territory accompanied by a reduction in green spaces and an increase in the number of stories significantly changed the ecological conditions in urban districts. The ecological situation has especially worsened in the Zheleznodorozhny and Industrialny Districts.

Conclusion

Our developed methodology included the following steps. At the preparatory stage, we reviewed and critically analyzed the methods used, identified the main factors determining the comfort of the environment. Then, we obtained quantitative and qualitative characteristics of the identified factors using cartographic and instrumental methods, as well as data from management bodies of environmental quality control. At the final stage, we conducted a qualitative assessment of administrative districts by the degree of the urban environment comfort.

The insufficient level of scientific developments in the research of urbanized territories has to be noted despite the progress achieved by now. At the same time, the research results concerning the relationships between ecological and socio-economic processes do not find an application in the practice of urban planning and the design of ecosystem services to improve the living conditions of all urban residents and increase the stability of cities [18].

Generally, the entire territory of the city of Barnaul is characterized by the problems associated with non-uniformity of site landscaping, congestion of highways, and an insufficient level of improvement of the entire territory and especially recreation areas. These things significantly reduce the level of living

ecological comfort in the city of Barnaul. In order to improve it, it is necessary to take real actions to enhance the urban infrastructure, primarily to optimize traffic flows, expand and create new zones of green spaces. The city especially needs green public spaces.

The performed analysis has highlighted the tight spots of each urban area, which must be considered while implementing municipal programs for the formation of a modern urban environment.

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