Application of Biosphere Compatibility Indicator for Assessment of the Effectiveness of Environmental Protection Methods

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Abstract. The article is devoted to the issue of using the biosphere compatibility indicator to assess the effectiveness of environmental protection methods. The indicator biosphere compatibility was proposed by the vice-president of RAASN (Russian Academy of Architecture and Building Sciences), Doctor of Technical Sciences, Professor V.I. Ilyichev. This indicator allows one to assess not only qualitatively but also quantitatively the degree of urban areas development from the standpoint of preserving the biosphere in urban ecosystems while performing the city's main functions. The integral biosphere compatibility indicator allows us to assess not only the current ecological situation in the territory under consideration but also to plan the forecast of its changes for the new construction projects implementation or for the reconstruction of the existing ones. The biosphere compatibility indicator, which is a mathematical expression of the tripartite balance (technosphere, biosphere and population of this area), allows us to quantify the effectiveness degree of different methods for environment protection to choose the most effective one under these conditions.

1. Introduction

The problem of preservation of the environment is based on the provisions of the concept of sustainable development, which served as the basis for developing strategies for the protection of the environment in most countries [1-5], including Russia. Despite the enormous positive role of sustainable development in international cooperation on the protection of the environment (agreement on limiting greenhouse gas emissions) and urban development [2], still not existed approaches to transition to biosphere compatibility city. In this regard, of particular interest is the concept of biosphere compatibility offered by Vice President of Russian Academy of Architecture and Construction Science, Doctor of Technical Sciences, Professor V.I. Ilyichev. [6]. The concept of biosphere compatibility is means the balance of biosphere and technosphere, for evaluation of this balance we can use as indicators of environmental pollution traditional values of industrial emissions compared to maximum permissible concentration, green areas, the intensity of a cleaner environment by recreational areas and other indicators of the anthropogenic impact on the biosphere.

2. Results and discussions

The general concept of hierarchy and relationships represented in the matrix of the transformation of the city in biosphere compatibility's city (Table 1) [7].

Table 1. Matrix development of urban areas based on the balance of homeostasis Biotechnosphere.

1. The harmonious coexictence of urban areas and the natural environment	4. Regalatory support maintaining the Balance of Biotechnosphere	7. Functions of the city, providing development of urban areas
2. Analysis of the interaction of the components of urban ecosystemes (emissions technosphere, biological objects, people)	5. Knowledge management as a basis biosphere compatibility processes in urban ecosystems	8. Reliability – program for the development of urban settlements based on the concept of biosphere compatibility
3. Balance Biotechnosphere – Triple drmographic, technosphiric biological indicators of urban ecosystems	6. Progress, a comparison of the planned parameters of urban ecosystems with actual	9. Knowledge – new approaches to the urban environment and the development of urban areas

In this approach, the numerical value of the biospheric compatibility is defined as follows [7]:

$$\eta = \sum_n \sum_i (D_{in} \cdot \xi_{in}^* \cdot \Theta_{in} - A_{in} \cdot \gamma_{in} \cdot m_{in}) \tag{1}$$

where the right side of this formula is a relative index of pure environment; left - a relative indicator of pollution from the technosphere with maximum concentrations that allow the development of urban area.

D_{in} - The ratio of the required area of the biosphere wich necessary to neutralize the pollution from the technosphere is based on the i-th source polution in the n-th function of the city; ξ_{in}^*- Uniformity coefficient of the biosphere, taking into account the different intensities of pollutants; Θ_{in} - the number of sources, pollution from which can be absorbed by the biosphere, in the zone of influence of the i-th source in the implementation of the n-th function of city; A_{in}- The amount of pollution from the i-th source in the implementation of the n-th function of the city for the territory of distribution of pollution; γ_{in} - The coefficient of reduction of pollution parameters from each source; m_{in} - The relative number of sources, pollution from which must be absorbed by the biosphere in the zone of influence of the i-th source in the implementation of the n-th function of the city.

For calculation of the ratio of the area of the biosphere in the region or district of the village needed to neutralize contaminants from (D_{in}) we had the formula [7]:

$$D_{in} = \{(V_{in} / \Theta_{in}) / k_{in}\} / S_{all} \tag{2}$$

where V_{in} - volume of contaminants from the i-th source for implementing the n-th function of city kg/year; k_{in} - the volume one pollutant wich absorb by 1 m^2 biosphere, kg/year; S_{all} - total area (m^2).

The value of parameter pollution from the i-th source in the implementation of the n-th function of the city (A_{in}) is calculated by the formula [7]:

$$A_{in} = (S_{con} / \Theta_{in}) / S_{all} \tag{3}$$

where S_{con} - the area of contamination from the i-th pollutant in the implementation of the n-th function of the city, m^2.

The numerical value of the integral indicator of biosphere compatibility varies in the limit from 0 (complete suppression of the biosphere by the technosphere) to 1 (no emissions of the technosphere and natural development of the biosphere).

With the help of this technique, it is possible to compare quantitatively the different territories of urbanized territories (neighborhoods, city districts, separate cities and settlements) according to the

level of development of both the human potential and the development index of the biosphere (as the most important factor providing comfortable and safe living conditions for the population) for planning the development of these territories [7].

The development of urban areas in modern conditions is impossible without the application of the methods of protect the main environments of urban ecosystems (atmosphere, lithosphere, hydrosphere, biosphere) and the population of urbanized areas from the effects of various types of pollution. It is very important to choose the method that will most effectively eliminate this type of pollution in this conditions. The effectiveness of a different methods and engineering solutions for environmental protection today is estimated by the economic criterion, which allows calculating the amount of costs for their implementation, as well as saving resources and money from their implementation [3]. Also, the ability of the method to reduce the degree of this type of pollution to the level of MPC. This approach allows us to quantify the parameters of the technosphere when we choosing a method or engineering solution. But the parameters of the development of the biosphere in this case (for example, the ability to accumulate pollution) are estimated only approximately (qualitatively) [8].

So, the methodology for calculating the integral index of biosphere compatibility is universal and allow not only qualitatively but also quantitative assessment of the effectiveness of various methods of environmental protection [9, 10].

As an example, we have analyzed the land territory Orel city as a typical regional center of Central Federal District of Russia [8]. The area of the Orel city is 1,452,000 m^2, industrial and communal storage areas - 16% [9]. The amount of generated waste is 64,000 t/year from 320,000 inhabitants, or 19,200 m^3/year from each resident ($V_{i=1}$). The area of the landfill for solid household waste (including a 500-meter sanitary protection zone) is 1,040,000 m^2, or 3.25 m^2 per inhabitant. The volume one pollutant wich absorb by 1 m^2 biosphere (k_{in}) is 0,024 kg/year. So we can calculate the ratio of the required area of the biosphere wich necessary to neutralize the pollution from the technosphere is based on the i-th source polution in the n-th function of the city (D_{in}) by formula 2.

$$D_{i=1} = \{(V_{in} / \Theta_{in}) / k_{in} / S_{all} = \{(19200 / 320000) / 0,024\} / 3,25 = 0,76$$

The area of contamination from the i-th pollutant in the implementation of the n-th function of the city is 124,000 $м^2$. So we can calculate the amount of pollution from the i-th source in the implementation of the n-th function of the city for the territory of distribution of pollution (A_{in}) by formula 3.

$$A_{in} = (124000 / 320000) / 3,25 = 0,12$$

Waste from the whole city is buried in the landfill area therefore $m_{i=1}=320000=100\%=1$. So the value of the indicator of biosphere compatibility for the Orel city is:

$$\eta = \sum_{n=1} \sum_{i=1} (D_{in} \cdot \xi_{in} \cdot \Theta_{in}) - (A_{in} \cdot \gamma_{in} \cdot m_{in}) = (0,76 \cdot 1 \cdot 1) - (0,12 \cdot 1 \cdot 1) = 0,64$$

Values of the indicator of biosphere compatibility shows that the environment is pressing by a human. Innovative methods of waste disposal reduce the human impact on the environment. The level of effectiveness of different methods of waste disposal can be assessed by using the indicator of biosphere compatibility. As an example, the construction of a waste processing plant is planned in the city of Orel. Part of the solid household waste will be recycled (48%) and the rest will be pyrolyzed in the gasifier to produce combustible gases. The gasifier is a shaft furnace with a working diameter of 1500 mm and a working part height of 5000 mm, equipped with devices for automatic fuel loading and unloading of ash residue and a control system. To implement this method, an inert heat-resistant material is loaded into the gasifier together with the fuel, which accumulates the heat of the exhaust gas and passes to the afterburner zone and transfers heat to the incoming air. The gasification process has a high efficiency (up to 95%), and the use of high temperatures (up to 1200^0 C) and the process of

binding pollutants with an ash residue can significantly reduce the concentration of pollutants in emissions to the atmosphere [7].

The territory of the plant will be located in 4 km from the Orel city in an easterly direction from the leeward side to the prevailing winds. The area of the plant with a sanitary protection zone is 800,000 m^2, or 2.5 m^2 per inhabitant (S_{all}), k_{in} - is 0.03 kg/year.

Figure 1. Scheme of waste disposal plant.

The ratio of the required area of the biosphere wich necessary to neutralize the pollution from the technosphere is based on the i-th source polution in the n-th function of the city (D_{in}) is:

$$D_{i=1} = \{(V_{in} / \Theta_{in}) / k_{in} / S_{all} = \{(19200 / 320000) / 0{,}03\} / 2{,}5 = 0{,}8$$

The value of the indicator of biosphere compatibility for Orel city in the application of the waste processing plant is:

$$\eta = \sum_{n=1}\sum_{i=1}(D_{in} \cdot \xi_{in} \cdot \Theta_{in}) - (A_{in} \cdot \gamma_{in} \cdot m_{in}) = (0{,}8 \cdot 1 \cdot 1) - (0{,}08 \cdot 1 \cdot 1) = 0{,}72$$

Comparison of these two values of η (0,64 and 0,72) shows that the utilization of the method of disposal of solid waste at the waste processing plant is more effective than traditional disposal at the landfill site by 22%.

3. Conclusion
Thus, the methodology for calculating the indicator of biosphere compatibility allows us to evaluate the effectiveness of different methods for improving the urban environment and choose the best one.

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