APPLICATION OF BIOINDICATION METHODS TO ASSESS THE IMPACT OF VEHICLE EMISSIONS FROM THE PERSPECTIVE OF THE CONCEPT OF BIOSPHERE COMPATIBILITY

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Abstract

This article is devoted to the application of biondication methods of various species urban green areas to assess the quality of the urban environment. To estimate we used different areas of the city Orel with different levels of human impact.

Key words: *biosphere compatibility, urban ecosystems, human impact, bioindication*

1. INTRODUCTION

In modern conditions, when urban development is not possible without focusing on a limited area of population, industry and transport, pollution reaches such proportions as the current system of environmental regulation quality of urban ecosystems can not fully perform its function of maintaining the balance of the biosphere and the technosphere (Vorobyov, S. 2013, Vorobyov, S. 2014). The positive effect of maintaining emissions at the MPC is breaking by the number of pollution sources (Vorobyov, S. 2015, Громова, ВС, Воробьев, СА & Гераськина, НП 2013). 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, 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, 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. 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 (Ильичев, В.А. Колчунов В.И., Воробьев С.А. 2007). The general concept of hierarchy and relationships represented in the matrix of the transformation of the city in biosphere compatibility's city. (Table 1) (Голенков, В.А., Воробьев, С.А., Козлов, Д.З. 2013).

Implementation of the second cell of the matrix is not possible without the current assessment of environmental quality of the urban environment as a starting point for predicting the development of urban areas and for development of environmental protection measures. As one of the promising methods for assessing the quality of the environment are the methods of bioindication. Methods compare favorably to traditional laboratory studies the major media (air, soil, water) simplicity, speed of execution and low cost. The use of bioindication methods does not require special education and allows to evaluate the quality of environment directly by city planner engineer.

Engineer designer can evaluate the impact on the environment by assess the state of greenery. To do this, he can use the methods of bio-indication. These methods differ in speed and ease of implementation (such as fluctuating asymmetry coefficient). They allow you to partition the same green planting on the degree of adsorption of contaminants. This is an important question because now in the concept of biosphere compatibility is considered as a homogeneous formation of uniformly absorb pollution (Ильичев, В.А. Колчунов В.И., Воробьев С.А. 2007).

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

1. The harmonious coexistence of urban areas and the natural environment	4. Regulatory support maintaining the balance Biotechnosphere	7. Functions of the city, providing development of urban areas
2. Analysis of the interaction of the components of urban ecosystems (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 balance demographic, technospheric and 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:

$$\eta = \sum_{n} \sum_{i} (Д_{in} \cdot \xi^{*}_{in} \cdot \Theta_{in} - A_{in} \cdot \gamma_{in} \cdot m_{in}) \quad (1)$$

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. $Д_{in}$ - 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 (Ильичев, В.А. Колчунов В.И., Воробьев С.А. 2007).

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

$$Д_{in} = \{(V_{in} / \Theta_{in}) / k_{in}\} / S_{общ} \quad (2)$$

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;

$S_{общ}$ - total area (m^2) (Ильичев, В.А. Колчунов В.И., Воробьев С.А. 2007).

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:

$$A_{in} = (S_{пол} / \Theta_{in}) / S_{общ} \quad (3)$$

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

The conception of expanded reproduction of the main productive forces can be written as:

$\eta > 0$; (4)

$\eta \leq 0$ (5)

With a positive balance of bio-and technosphere (see formula 4) provided the main productive force growth and natural population growth, otherwise (see formula 5) holds regressive development of territory (Ильичев, В.А. Колчунов В.И., Воробьев С.А. 2007).

2. MATERIALS AND METHODS

As an example, we have analyzed the land territory Orel city as a typical regional center of Central Federal District of Russia. To detect anthropogenic impacts on urban ecosystems we have identified ecotopes - land urban areas with similar parameters of the biosphere (the area and species composition of green territories), the technosphere (polluters), demographic (number of inhabitants) and urban development (type of building, the proximity of industrial enterprises, roads) factors. As these areas we have chosen the following areas: the area adjacent to the housing number 7 (Moscow street 77) State University - ESPC (area 1), the park near main building Oryol State Universitry (Komsomolskay street 166) (area 2), area adjacent to the Museum of Oryol writers (area 3). All of these areas are characterized by the similar buildings (five-storey buildings, the lack of high-rise buildings, flat terrain), the characteristics of human impact (prevalence of vehicle emissions from major highways), similar areas (about 4 ha), the same composition of green spaces (the main tree species are the English oak, Norway maple and heart- linden, plants of the same age and size), the same number of inhabitants (about 14,000 people). All of these areas are characterized by the same set of factors of anthropogenic impact and varying degrees of quantitative manifestation of these factors. As a control area that not feel the impact of these factors, we have chosen the area of Medvedevsky forest (area 4).



Fig. 1. Location investigated areas

The main source of pollution at all this sections was selected vehicles, as it accounts for a significant part of the emissions in atmosphere Oryol. To determine the number of vehicles for the subsequent calculation of emissions, at study sites were counted in the rush hour, within a year. Noted the number of cars in 30 minutes, followed by recalculation of 1 hour. Car traffic was divided into categories: passenger road transport; cargo, with a diesel engine; truck, with a carbureted engine; bus, diesel engine; with carburetor engine bus; trolley bus; minibuses. Separation was made to more accurately assess the environmental burden, as each of these categories is characterized by a specific set of emissions. Traffic is amounted 2067, 1528, 1231 cars in hour, for areas 1, 2 and 3 respectively.

The main source of contamination at all study sites were selected vehicles, as it accounts for a significant portion of the emissions in the city of Orel (Городков, А.В., Воробьев С.А., Карпешина Н.А. 2013). To determine the amount of pollutants from vehicle emissions has been used a technique developed by A. Voeikov (Воейков, А.И. 2008).

To assess the quality of the environment, we used the method of calculating the index fluctuating asymmetry, is, the variance based on the difference between the sides are not zero, and from some differences between the parties taking place in the given sample and calculated as follows:

$$\sigma^2 = \frac{\sum(d_{i-r}-M_d)^2}{n-1} \quad (6)$$

where d_{i-r} - the average difference between the parties;

M_d - difference of characteristic values.

These indices are calculated by the following formulas:

$$M_d = \frac{\sum d_{i-r}}{n} \quad (7)$$

$$d_{i-r} = \frac{2(d_i-d_r)}{d_i+d_r} \quad (8)$$

d_i - value of characteristic on the left side,

d_r - value of characteristic on the right side,

n - sample size.

Processing plant sample in determining the coefficient of fluctuating asymmetry is measuring the lengths of the veins on the leaf blade right and left (Громова, ВС, Воробьев, СА & Гераськина, НП 2013).

We investigated the main tree species in Orel (oak (Quercus robur L.), maple (Acer negundo L.) and linden (Tilia cordata Mill)) which accounted for 80% of all green spaces. Plants were chosen the same age and size. Foliage urban green space was selected according to accepted procedures in the lower part of the crown at arm's length with the side facing the roadway. The leaves were collected one part of the medium sized type.

3. RESULTS AND DISCUSSION

We obtained the following results on the emissions of vehicles on the study areas (Table 2):

Table 2 - Distribution of total and maximum single emission investigated areas

investigated areas	indicator	
	Total emissions, t / year	The maximum single ejection g / s
area 1	13454	15,2789
area 2	10274	1,0471
area 3	9338	0,8971

To clarify the mutual influence of vehicle emissions on the investigated areas in Orel, we have analyzed the meteorological data, summarized in Table 3. These data represent the average number of prevailing winds for 2014 year.

Table 3 - Interference investigated areas in the context of wind direction

contaminated areas	polluting areas		
	area 1	area 2	area 3
area 1	N, N-E, E, S-E, S, S-W, 3, C-3	S-E	S-W
area 2	S-W	S, N-E, E, S-E, S, S-W, W, S-W	W
area 3	S-E	E	N, S-W, E, S-E, S, S-W, W, N-W

Then calculations were made using the procedure described in (В.А. Ильичев, В.Н. Азаров, Т.В. Донцова, 2013). Results are summarized in Table 4.

Table 4 - Formation of pollutants at investigated areas in view of the air transport

area	Emissions t / year
1	19619
2	12419
3	9153

The analysis of the above table shows that, given the volume of the air transport of pollutants in the area 1 rose by 45%, on a area 2 increased by 21%, and in the area 3 decreased by 2%. This is due to the predominance of winds western and southern direction of the geographical location of the Orel.

When we analysed bioindication methods on the investigated areas we obtained the results: (Table 5):

Table 5 - Area of leafs of green spaces.

Areas¤	Tree·leaf·area·of·urban·green·spaces,·cm².¤		
	oak¤	maple¤	linden¤
Area·1¤	15,20¤	20,70¤	14,50¤
Area·2¤	19,70¤	25,30¤	16,05¤
Area·3¤	26,30¤	36,70¤	20,30¤
Area·4·(control)¤	27,50¤	44,30¤	24,20¤

Common to all of those species examined trends relates the fact that the area of leafs with decreasing the number of vehicles is increasing and is the highest in the control group of plants. The biggest area of leafs for all three species (after the control group) is marked on the area 3, then area 2 and the smallest in the area 1. Thus, we have the effect of vehicle emissions on the studied plants, which is higher in those areas where more number of cars. But each breed has their differences.

Leaf area of maples (Acer negundo L.) is the highest among the studied species of urban green space, which is related to species characteristics of the breed. The largest area of leafs is in the control group (area 4), then by area 3, area 2 and the minimum area is marked to plants area 1. The difference between the highest and lowest value was 2 times.

Thus, the observed correlation between the number of vehicles and the amount of leaf area on the test plants. This dependence confirms the correlation coefficient constituting r = -0,92.

Average values of leaf area of oak less than maple, but more then linden, is also associated with species characteristics. The highest values of leaf area also fall on the plants in the control group (section 4). The difference between the highest and lowest values is also 2 times.

The correlation coefficient values of the leaf area of oak and vehicles on study sections is r = -0,96 and indicates a pronounced inverse relationship.

Average values of leaf area linden is lowest among the studied species of urban green spaces. The highest values of leaf area in the breed also fall on the plants in the control group (area 4) and the whole dynamics of the distribution of leaf area linden on tested areas looks the same as in the previous two cases. Differences between the linden leafs on the areas are not as big as the other species studied urban green space this fact indicates the greater stability of this breed compared to other breeds.

To assess the impact of pollutants we used the method of study of fluctuating asymmetry coefficient, the values of which are given in Table 6.

Table 6 - Values of the coefficient of fluctuating asymmetry

Areas¶ ¤	Fluctuating·asymmetry·coefficient·values·for·plants¤		
	oak¤	maple¤	linden¤
Area·1¤	0,025¤	0,020¤	0,017¤
Area·2¤	0,023¤	0,017¤	0,·015¤
Area·3¤	0,020¤	0,014¤	0,010¤
Area·4·(control)¤	0,006¤	0,005¤	0,005¤

On the storage capacity of green space influenced by many factors, from weather conditions to species composition, because different types of urban green spaces are characterized by unequal resistance to absorbed pollutants. Thus, the biosphere compatibility can be calculated by the formula:

$$\xi^* = 1 - (S_{озел} \cdot \sigma) \quad (9)$$

where

$S_{озел}$ - the total area of green spaces ;

σ - coefficient of fluctuating asymmetry .

Using the above formulas were obtained the following results shown in Table 7.

Table 7 - Values of the coefficient of uniformity of the biosphere on the studied sections

indicator¤	studied·areas¤			
	area·1¤	area·2¤	area·3¤	area·4¤
ξ*	0,15¤	0,19¤	0,23¤	0,79¤

Substituting the values obtained in the formula (1) we received updated information (Table 8)

Table 8 - Values of the coefficient biosphere compatibility on the studied sections

indicator¤	studied·areas¤			
	area·1¤	area·2¤	area·3¤	area·4¤
ή	0,24¤	0,32¤	0,41¤	0,97¤

From the obtained values of the biosphere compatibility can be concluded that the current state of ecosystems at all studied areas indicates the presence of degradation processes due to anthropogenic impacts that the biosphere cannot fully accumulate pollution and regenerate the city ecosystem.

4. CONCLUSIONS

The highest values of the coefficient fluctuating asymmetry observed in plants maple on all three points, followed by plant oak and linden lowest observed. In plants of all three species investigated urban green spaces greatest values of the index of asymmetry observed at the area №1, then area №2, №3 and the lowest in the area №4.

In control group the coefficient asymmetry values is smaller than in the samples at investigated areas, and their differences are not so obvious that due to the fact that in a relatively favorable from an environmental point of view the conditions the plants are not exposed to stress like in urban environments. In an urban setting green spaces show better ability to adapt. That's why the difference in biological indicators are more obvious. Distribution of values of the coefficient fluctuating asymmetry coincides with the dynamics of the distribution of the emissions in the investigated areas.

There is a direct correlation of coefficient asymmetry of green space and emissions at study sites, as indicated by high values of the correlation coefficient of this factor (0.95). The influence of meteorological factors, which manifests itself in the predominance of winds west and south directions, is increased human impact on area №1 by the air pollution from areas №3 and №2. Our future investigations will be associated with the improvement of methods of assessing the quality of the

environment, based on the concept of biosphere compatibility with the influence of the prevailing direction of air flow in an urban environment as an important factor in enhancing anthropogenic impact.

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