The determination of the integral biosphere compatibility indicator of urban areas by bioindication’s methods

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Abstract. In modern conditions, urban development is impossible without concentration of population, industry and transport in a limited area. The environmental pollution reaches such proportions that the positive effect of keeping emission of pollutants at the level of the MPC is leveled by number of pollution sources, their concentration in a limited area and the synergistic effect of the pollutants on human health. There is a need to assess the quality of the urban environment. This is especially important inside city blocks. Residential areas are separated from industrial by sanitary protection zones, but road transport easily penetrates into a residential area and its emissions affect public health. The methods of bioindication is a quick, affordable and cheap way to assess the quality of the environment. Bioindication methods are also a reliable source for determining the integral indicator of the biospheric compatibility of urban areas.

1. Introduction

In modern conditions of consumer attitudes for environment, the choice of strategy and tactics for ensuring integrated security, which require the systemic integration of scientific research and the efforts of various specialists, plays a crucial role (Bakaeva N, 2017). However, today there is no reliable theory that reflecting the interdisciplinary knowledge and specifics of managing the integrated security of the natural-socio-technical systems of urban areas as a self-regulating system (Ilyichev V.A. et al, 2018).

That is way the concept of biospheric compatibility of regions, cities and settlements formulated by the Russian Academy of Architecture and Construction Sciences under the guidance of academicians V.A. Illichev, A.M. Karimov, V.I. Kolchunov is interesting (Ilyichev V.A. et al, 2017). This theory is a single comprehensive study of the formation of socio-economic and humanitarian mechanisms for the progressive development of people, technology and the biosphere. Within this concept, the essence of the progressive development of cities lies in the expansion of the symbiosis of the Biosphere and human. The progressive development of urbanized areas and the level of human potential must be considered criteria for the process of creating innovations (Ilyichev V.A. et al, 2017).

Creating a biosphere-compatible territory is impossible without a current assessment of the quality of the urban environment, as a starting point for forecasting the development of urbanized areas and environmental protection measures. One of the most promising methods for assessing the quality of the environment is bioindication, which compares favorably with traditional laboratory methods for studying basic media (atmosphere, soil, water) by simplicity, speed of work and their low cost.
The use of bioindication methods does not require a special education and allows to assess the environment directly to the engineer-town planner (Vorobyov S., 2019).

As a test object for the study of bioindication methods, it is advisable to use green space (Tkachenko Alla., 2015). Urban green spaces are used in the formation of urban landscapes, performing many useful functions, the most important of which is environmental protection.

2. Goal of the study
The goal of our study was to assess the quality of the urban environment using such bioindication methods as calculating the fluctuating asymmetry coefficient and investigating the phytotoxicity of precipitation by germinating cress seeds, using the example of the Orel city residential district as a typical regional center of the European part of Russia.

To achieve this goal, we chose a part of a residential area bounded by two roads: on Moskovskaya Street and Gruzovaya Street. Inside the area is dominated by a five-story building. Thus, this area is characterized by the same urban characteristics (Figure 1).

![Figure 1. Researched area](image)

3. Case study
To determine the number of vehicles for the subsequent calculation of emissions, at the sites of the study were calculated at rush hour during 2018. Marked the number of cars in 30 minutes, followed by recalculation in 1 hour. The traffic was 1528 and 904 vehicles per hour, for areas 1 (Moskovskaya street) and 2 (Gruzovaya street), respectively. The main source of pollution in all research areas are cars. To determine the amount of pollutants from vehicle emissions, a technique developed by A. Voeikov OND-86 was used (A. Voeikov, 1986).

The following results were obtained on vehicle emissions in the researched areas (Table 1):

Table 1. Distribution of gross and maximum one-time emissions in the researched area

| Area                | Amount of emissions |  |
|---------------------|---------------------|--|
|                     | Gross emission, [t/y] | Maximum one-time emissions, [g/s] |
| 1 (Moskovskaya street) | 13454               | 15.2789 |
| 2 (Gruzovaya street)     | 9265                | 0.8374  |
To identify the impact of vehicle emissions on the distribution of pollutants in precipitation, samples were taken at the points shown in Fig. 1. Samples were taken from December 2018 to March 2019. Selected samples were tested using the complexometric method to determine the total hardness, the method of extracting exchangeable hydrogen ions to determine the acidity and the trimetric method to determine the mass concentration of sulfates. These methods correspond to RD 52.24.395-2017, GOST 17.4.4.02 (ISO 14001:2015) and PND-F 14.1: 2.107-97 (ASTM D4739-08).

We obtained the following results (Table 2):

**Table 2. Distribution of pollutants in precipitation samples**

| Sample Point Number | Indicator | Sulfate concentration, [mg/dm³] |
|---------------------|-----------|---------------------------------|
|                     | Hardness, [°H] | Acidity, [pH] |                                |
| 1                   | 8          | 5.5               | 16                              |
| 2                   | 5          | 6.5               | 12                              |
| 3                   | 4          | 6                 | 10                              |
| 4                   | 7          | 5.5               | 14                              |
| 5                   | 7          | 5.7               | 18                              |
| 6                   | 6          | 6                 | 14                              |
| 7                   | 4          | 6.1               | 10                              |
| 8                   | 5          | 6.5               | 12                              |
| 9                   | 7          | 5.5               | 16                              |
| 10                  | 8          | 5.0               | 19                              |
| 11                  | 6          | 5.8               | 17                              |
| 12                  | 5          | 6.0               | 15                              |
| 13                  | 4          | 6.5               | 10                              |
| 14                  | 7          | 5.5               | 14                              |

To determine the phytotoxicity of precipitation, we used the method of germinating watercress seeds on selected samples. The following results were obtained (Table 3).

**Table 3. The results of germinating crescent on selected samples**

| Sample Point Number | The average length of seedlings, mm |
|---------------------|-----------------------------------|
| 1                   | 27.5 ± 0.32                       |
| 2                   | 29.7 ± 0.34                       |
| 3                   | 39.3 ± 0.28                       |
| 4                   | 32.6 ± 0.34                       |
| 5                   | 25.6 ± 0.27                       |
| 6                   | 30.5 ± 0.22                       |
| 7                   | 39.6 ± 0.29                       |
| 8                   | 42.2 ± 0.32                       |
| 9                   | 38.4 ± 0.25                       |
| 10                  | 24.6 ± 0.27                       |
| 11                  | 28.4 ± 0.23                       |
| 12                  | 31.5 ± 0.28                       |
| 13                  | 39.6 ± 0.34                       |
| 14                  | 37.1 ± 0.28                       |

To identify the asymmetry index, trees of the same age of the linden breed prevailing in a researched area were selected. Samples were taken at the points shown in Fig. 1.

We obtained the following results (Table 4, Figure 2):
Table 4. The value of the indicator of fluctuating asymmetry

| Sample Point Number | The value of the indicator of fluctuating asymmetry, $\sigma_x$ |
|---------------------|---------------------------------------------------------------|
| 1                   | 0.0646                                                        |
| 2                   | 0.0532                                                        |
| 3                   | 0.0478                                                        |
| 4                   | 0.0592                                                        |
| 5                   | 0.0659                                                        |
| 6                   | 0.0592                                                        |
| 7                   | 0.0432                                                        |
| 8                   | 0.0497                                                        |
| 9                   | 0.0567                                                        |
| 10                  | 0.0694                                                        |
| 11                  | 0.0601                                                        |
| 12                  | 0.0532                                                        |
| 13                  | 0.0453                                                        |
| 14                  | 0.0587                                                        |

Figure 2. Distribution of fluctuating asymmetry.

Thus, the values of the asymmetry coefficient are distributed over all the tested lines (1-4, 5-9, 10-14) equally. Maximum values are noted at a distance of 15 and 150 meters from Moskovskaya Street. The minimum values at a distance of 80 meters from Moskovskaya Street.

4. Summary
The concentrations of pollutants in samples of precipitation are maximum at points adjacent to the streets (more from Moskovskaya St.). For all researched lines (1-4, 5-9, 10-14), the values of the indicators decrease inside the residential block, which is confirmed by high values of the inverse correlation coefficient of the distance from the road and the value of the indicator ($r = -0.8$). The phytotoxicity of precipitation is directly proportional to the concentration of pollutants, since the length of seedlings is inversely proportional to these values.

Analyzing the distribution of indicators of fluctuating asymmetry along the lines 1-4, 5-9, 10-14, the following regularities can be identified: the values of the indicators are maximum at points adjacent to the streets (more so from Moskovskaya St.) (Fig. 2); for all the researched lines, the values
of indicators decrease inside the residential block, which is confirmed by high values of the inverse correlation coefficient of the distance from the route and the value of the indicator ($r = -0.8$); at the same time, the values of indicators for different lines are different, which suggests the influence of intra-local factors and requires further research.

References

[1] Bakaeva N 2017 *Technique for Reduction of Environmental Pollution from Construction Wastes* / (IOP Conf. Series: Materials Science and Engineering) 262 012195.

[2] Ilyichev V A, Emelyanov S G, Kolchunov V I, Bakayeva N 2018 *Principles of Urban Area Redevelopment for Safe and Comfortable Living conditions* (IOP Conference Series: Materials Science and Engineering (MSE)).

[3] Ilyichev V A, Bakaeva N, Chernyaeva I V, Vorobyov S A 2017 *Evaluation of the performance of biosphere compatible city functions in modern residential areas* (Journal of Applied Engineering Science) 15(468)(4) 447-454.

[4] Vorobyov S 2017 *Distribution of Heavy Metals in Soil of Urban Ecosystems by the Example of the Oryol City* (IOP Conference Series: «Earth and Environmental Science») 66. doi:10.1088/1742-6596/755/1/01100.

[5] Vorobyov S 2019 *The Impact of Vehicle Emissions on the Rate of Asymmetry of Urban Spaces on the Territory of Urban Districts* (IOP Conf. Series: Earth and Environmental Science) 224 012040. doi:10.1088/1755-1315/224/1/012040

[6] Tkachenko A 2015 *Monitoring the content of toxicants in the air* (Journal of International Scientific Publications - Ecology & Safety) 9.

[7] Voeikov A 1986 *OND-86: Method of calculating concentrations in the air of harmful substances* (Moscow, Hydromet).