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Opinion

Approaches to Formalizing the Combined Effects of Technogenic Factors, Including Ionizing Radiation, on Biota

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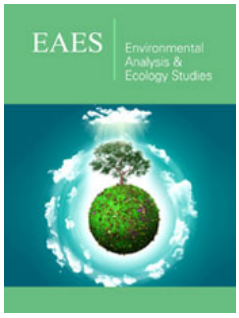

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Opinion

In natural conditions, biota is exposed to a variety of environmental factors of biotic and abiotic nature, which, as a rule, have a combined effect on the passage of ecological processes. This is the subject of interest of factorial ecology (autecology). In addition, the biosphere has long been under the influence of various kinds of man-made factors that can also have a joint impact. Environmental pollution with several ecotoxicants at once and in combination with ionizing radiation is quite common. Thus, we can talk about expanding the sphere of interests of factorial ecology and including in it already three groups of exogenous and endogenous factors: abiotic, biotic and technogenic (anthropogenic).

To predict the simultaneous impact of a number of factors of different nature on individual organisms, their communities, ecological systems and the biosphere as a whole, it is necessary to formalize our ideas about this phenomenon. In traditional factorial ecology, the formalization of ideas about the combined effects of environmental factors has already received its interpretation (see for example: Fedorov VD et al. [1]). However, the violation by man of the already established conditions for the functioning of biological and biosystem systems, the expansion of the spectrum of man-made impacts has long dictated the need for a new approach to solving this issue. The primary solution to formalize information about the impact of several factors on an object is to conduct a full factorial experiment and use multiple regression analysis. It should be noted, however, that the impact of factors may be nonlinear, and the interaction of factors with each other is also possible, which significantly complicates this task.

If we proceed from the definition of a combined action as the simultaneous impact of several factors, then when considering the example of a two-factor impact, the following generally accepted options are possible:

A. Additive action- the action of factors is summed up. The total effect is equal to the sum of the effects of all the factors of influence.

B. Synergism- enhancing the effect, one factor enhances the effect of the other.

C. Antagonism- one factor weakens the effect of the other.

D. Independent action- the combined effect does not differ from the isolated action of each factor. The effect of the most potent factor prevails.

In the case of more factors, the picture will be more complex. It should also be taken into account that the impact of the same factor, depending on any external or internal conditions, can be multidirectional, and its interaction with other factors of influence can also be ambiguous. Also, the methods of exposure to the same object may be different and have a different effect, for example, the ways in which an ecotoxicant enters the body or the external and internal effects of ionizing radiation. To account for the damage to the biota and

its components from the effects of various factors, it is possible to use equidosimetry approaches used in radiobiology and borderline fields of knowledge [2], considering as a damaging agent not only various types of ionizing radiation, but also ecotoxicants.

Possible Approaches to Formalization of Combined Impact in Ecology

A common method of formalizing phenomena in factorial ecology is the use of multiple regression analysis. This method is used in ecology to study the possibility of predicting changes under the influence of two or more factors of any parameter of the functioning of an ecological object based on data obtained during preliminary studies.

Another way of formalization in this area can be an approach from the standpoint of mathematical analysis, i.e., the selection of a universal mathematical formula reflecting the observed patterns of the combined influence of environmental factors on organisms and ecosystems. In this case, private factors with their share of influence are combined into complex factors. The proportion or otherwise the weight of factors reflects the local features of the environmental impact on the body [3].

From our point of view, the most adequate tool for displaying such situations in a formalized form is simulation modeling. The implementation of a mathematical model in the form of a computer program allows you to take into account and display the impact of almost any possible combinations of factors, the reaction of the object to which is represented in the form of particular response functions.

When simulating a set of impacts on an object, you can use the concept of "the space of environmental factors" [1] and operate within this space, selecting mathematical equations, the so-called response functions that quantitatively characterize the influence of one or several factors on the object as a whole or its individual properties. These can be, for example, growth rate, productivity, mortality, etc. The forms of particular response functions can be very diverse. The most typical dependences of the functions of a biological object on various factors in two-dimensional space can be displayed by straight lines, exponents, parabolas, sigmoidal curves. Piecewise defined functions are often used, which may have thresholds, triggers, plateaus, etc.

The next key point in the formalization of the combined effects of several factors is the assessment of the importance of factors and options for taking this into account. If we use the laws of Liebig's minimum and Shelford's tolerance and single out the most important factor that is most significant for our object, then the remaining factors can be ignored. Then the algorithm is reduced to the inclusion in the model of the corresponding equation reflecting the dependence of the functioning of the object on this limiting factor. However, such situations practically do not occur in nature. The importance of a factor is a variable value, in certain conditions or at a certain time interval, another factor may come out on top. In addition, it is necessary to take into account the possible interaction of factors, as already mentioned above. Ecological processes, by their very nature, rather fall under the law of the cumulative effect of the Mitcherlich-Baule factors, and their passage depends on the totality of the factors acting simultaneously.

To reproduce the functioning of ecological systems of different levels, which are influenced by various factors interacting with each other, we have developed and are improving the algorithm EcoCombi. Based on this algorithm, a model is constructed that reproduces the dynamics of the number or biomass of living components of biological systems that are under the combined influence of two or more factors.

It should be noted that localization of models of combined impact of factors is a complex problem. The main difficulty is the lack of quantitative information about the nature of the impact of man-made factors on biological objects. Integration of disparate information is necessary. For this purpose, we are creating the information system CombiData, which is designed to collect, store and analyze data on the combined effects of various types of factors on biota.

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