ЕКОЛОГІЧНА БЕЗПЕКА

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RESEARCH OF THE USE OF «ECOLOGICAL NICHE» MODEL FOR DEFINITION OF PRODUCTION RISK INDICATORS

Abstract. *The issues of improving the methodology for determining the risk of labor activity using the model of «ecological niche» are considered in the presence of a number of harmful and dangerous factors for human beings in the production environment. The possibility of using an ecological niche for mathematical modeling and industrial risk indicators has been established, but it has been proved that it is necessary to consider that the response to one factor may depend on the influence of another of the existing harmful and dangerous production factors. This approach allows us to develop a multi-criteria mathematical model for determining the production risk, but it is necessary to take into account the changes in the parameters of the MHF, which complicates the problem, since the effects of the exceedances in the same percent are different for all harmful and dangerous production factors.*
Key words: *industrial environment, risk, ecological niche, hyper volume, algorithm.*

Analysis of the status of the question

It is known that a person, as a species, has its own «ecological niche» or a set of requirements for the set of ecological factors, formed in the process of evolution. The space in which this niche is localized is a place where their parameters do not go beyond inherited from their ancestors, but limited tolerance. An ecological niche includes a complex of biocenosis joints and requirements to environmental factors.

The term «ecological niche» was introduced by J. Grinnell in 1914, but he remained not developed and used little in scientific circulation until 1927 when the British ecologist Charles Sutherland Elton gave the first conceptual definition of this concept. Moreover, the definition of Grinnell called the «spatial niche» which is understood as «location», and the definition of Elton – «trophic niche», since the ecological niche is a combination of factors of the existence of this species, the main

of which is its place in the food chain [1]. In particular, he said: «If the ecologist says: «here is a badger run», he should have in mind some concept of the location of this animal in the group to which it belongs, as well, and when he says «here comes the priest». In the future the concept of an ecological niche was popularized by zoologist J. Hutchinson in 1958.

Despite the expansion in the development of a society of its properties and capabilities, the ecological niche of the person practically did not change. To survive, it overcomes the resistance of the limiting factors of the environment with the help of its protective devices, for example, to normalize the parameters of the microclimate and illumination of the housing, which imitate this niche, rather than solve this issue by adaptation. But, in circumstances that cause the production environment due to various reasons (organizational, technical, psychophysiological), this does not always happen.

Nowadays, when laws of the prediction of its technological development are already in force in the society, at the workplaces of each particular enterprise there are at least some of the whole list of harmful and dangerous production factors (HDPF). They are usually associated with dustiness, gas pollution, violations of microclimate parameters, noise, vibration, electromagnetic fields, etc., as well as with psycho-physiological effects (monotony, fixed work-human-operator posture, physical strain, fatigue, stress, etc.). Their periodic or permanent action on the human body leads to its passage beyond the comfort (tolerance), resulting in accidents (RA) with traumatic consequences, short-term health disorders or occupational diseases.

Setting objectives

The existing system of occupational safety management (OSM), as well as employees, from the working professions and the administration, do not have time to rebuild and provide, not even comfortable, but safe conditions for human functioning in the production environment with modern technology development and technologies. Also, the use or processing of the production conditions of natural resources inevitably leads to the formation of secondary material and energy products that dissipate in the environment. They are destructive elements of the ecological niche since, in relation to their maximum permissible levels, the stability of the human body does not increase. The ecological niche was also defined by J. Hutchinson as a «hyperbole», under which he meant the multidimensional space of resources (light, nutrients, suitable living places, etc.) available and used by certain species of organisms.

Therefore, any ecological niche, including in production conditions, can be represented as an n-dimensional cube, on the axes of which environmental factors are laid by the existing «model hyper volume» of J. Hutchinson. A hyper volume is a measure (usually the Lebesgue measure) of a generalization of a three-dimensional volume, using which the interiors of «hyper bodies» (bodies in a multidimensional space) are juxtaposed. Therefore, the area in the surrounding production environment can be represented as a set of HDPF, including anthropogenic, and choose from them those that affect the well-being of a person.

This approach makes it possible to develop a multi-criteria mathematical model for the definition of industrial risk. But, unlike the assumptions adopted in the model of J. Hutchinson, it must be taken into account that the response to one factor may depend on the influence of another of the available [2]. Moreover, since the

parameters of the HDPF, as well as the industrial premises, working areas, and places, are normative values, for example, according to [3, 4], this makes it possible to create a reliable mathematical model. It can be presented in the software, which allows developing the SOUP by improving the methodology for determining the production risk [5, 6].

Materials and research results

In spite of the fact that the exact calculation of a hype value of a set of d points of an n-dimensional space is a somewhat difficult task, however, in [1] a useful approximation is possible, namely by polynomials on the number of parameters and solutions, and also on its quality. And in [7] it is pointed out that there are several computer algorithms for accurate calculation of the hyper volume:

– Inclusion-Exclusion Algorithm (IEA), which is the easiest to find hyper volume and is based on the idea of a combinatory-on-off formula. In it, the entire set X is represented as a union of n hyper parallelepipeds (X^i) corresponding to separate points x^i. The formula calculates the volume of the whole set:

$$S(X) = \sum_{I \in 2^n} (-1)^{|I|+1} S(\bigcap_{j \in I} X^j), \quad (1)$$

and the volume of the intersection of hyper parallelepipeds is easily determined as a plurality for each coordinate of its minimal value among all the points corresponding to the specified parallelepipeds. In this algorithm, all subsets of aspects of the set X are traversed, for each of them there is a hyper volume of the intersection of the corresponding hyper parallelepipeds, which is appended with the similar sign to the resulting value. The operating time of this algorithm is O (n 2^n);

– the LebMeasure algorithm, which handles the points of the set X in turn. For each regular position x, there is a volume of some maximum hyper inclusion of a parallelepiped that is exclusively dominated by this point x, which is replaced by a particular set of generated points dominated by the residual domain dominated by this point x. The time of the algorithm depends directly on the number of generated points, which is not more than n^d since each coordinate of each of them is equal to the corresponding coordinate of some point of the initial set X;

– the Hypervolume by Slicing Objectives (HSO) algorithm, whose name refers to the coordinates of the space R^d for Objectives. If LebMeasure alternates all the points, then the HSO algorithm, in the same way, is all coordinates, reducing the task to less than one dimensional dimension. Thus, the initial set is divided into several disjoint hyper parallelepipeds, and it remains to find their total hyper volume. The running time of the algorithm depends directly on the total number of parts that will be broken into the initial set. Similarly, to the LebMeasure algorithm it is proved that the parts are no more than n^d, but there is a more accurate estimation of them;

– reduction in Klee's Measure Problem (KMP) task, whose task is to find the volume of rectangular hyper-parallelepipeds in dimensional space. In the description to the IEA algorithm, it is shown that the initial problem is reduced to the specified one, if at each point the hyper parallelepiped with one vertex in the coordinate center is aligned, and the opposite is at that point. There are various algorithms for solving the KMP problem, the most optimal of which is the use of the ideas of the scanning hyperplane, root heuristics, and k-d tree, which allows it to be solved in time $O\ (n^{d/2})\ log\ n$ [8].

But from the point of view of the implementation of these algorithms for precise calculation of hyper volume in determining the effects of the HDPF on a person in production conditions, the main task is not only to find the volume of human received doses of excess maximum permissible concentrations (MPC), maximum permissible levels (MPL), and the characteristics that accumulate these consequences. Recently, the main among such is the reduction in the duration of human life in days or years [5, 6]. So, in particular, the legislation of the Russian Federation uses the following name [9]. Some researchers [2] and regulatory documents have established the existence of such a reduction in the life that occurs when a person is found to be in a production environment with constantly acting excessive values of noise, vibration, dust, gas pollution (forging and rolling mills, flour mill combines) [5]. But there are two questions. First, under the influence of the same SOMP, the level of its exceeding of the normalized parameter during production time may be different, and accordingly, a dose of the negative consequences of such an action is obtained. Secondly, gender, age, general and professional experience, as well as the lifespan during which such excess was maximal must be taken into account.

That is, if in the coordinate system X, Y, Z (fig. 1) along the axis of the OX, to postpone the degree of excess of the HDPF of the normalized parameter Q, (%), along the OZ axis, the duration, or the term of such an excess t, (months), and along the axis OY – the term of lost life T (days), then it is possible to determine the hyper volume of the harmful effects of HDPF and to demonstrate that the finding of the point K1 in this volume is the consequence of those Q_1 and t_1, which lead to a specific level T_1. It is clear that the complete informative picture gives the presence of non-fixed Q and t values, and those that are changing, but in spite of this, in the first approximation, according to the data of job placement, you can determine the value of T. This raises the question of summing hyper volume of such influence, and after it and T during the working day, month, year, which does not cause significant difficulties.

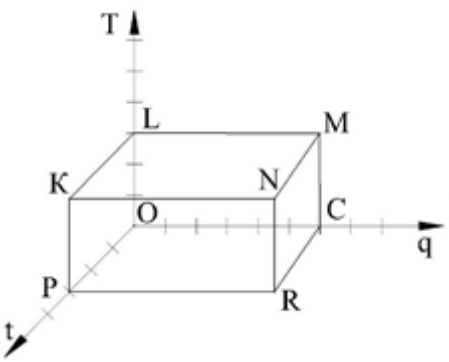

Fig. 1 – Determination of the hyper volume of the harmful effect of one of the HDPF

So, for example, in Fig. 2 shows that when the specific HDPF is exceeded during the working shift of the normalized parameter by 10% for 1 hour, by 15% for 2 hours and by 30% for 4 hours, there are hyper levels of their effect on a person, limited for the first case of the parallelepiped $K_1L_1M_1N_1R_1P_1O_1C_1$, for the second parallelepiped $K_2L_2M_2N_2R_2P_2O_2C_2$, for the third parallelepiped $K_3L_3M_3N_3R_3P_3O_3C_3$. But at the same time defining is the definition of the total T, which is calculated by the results of compilation:

$$T = OL_1 + OL_2 + OL_3.$$

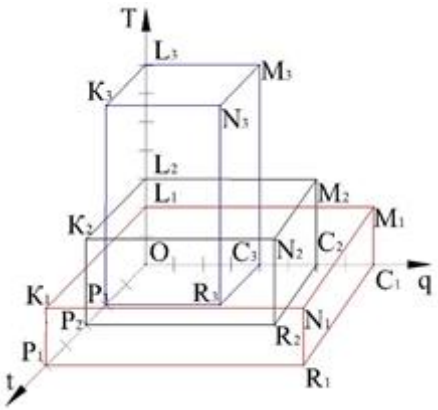

Fig. 2 – Determination of the hyper volume of the harmful effects of several HDPF

It should be noted that while the simultaneous operation of several HDPF raises the question of determining T as a result of their synergistic action, it is necessary to take into account also the indicated changes in the parameters of the HDPF, which significantly complicates the solution of the problem, since the effects of the exceedances in the same percent are different for all HDPF.

Conclusions

Thus, as a result of the study, it is possible to use the «ecological niche» model to improve the methodology for determining industrial risk indices, but, unlike the assumptions adopted in the model of J. Hutchinson, it is necessary to take into account that the response to one factor may depend on the effect of another of the existing HDPF.

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ДОСЛІДЖЕННЯ ПРОБЛЕМ ВИКОРИСТАННЯ МОДЕЛІ «ЕКОЛОГІЧНОЇ НІШІ» ДЛЯ ВИЗНАЧЕННЯ ПОКАЗНИКІВ ВИРОБНИЧОГО РИЗИКУ

Анотація. Розглянуто питання удосконалення методології визначення ризику трудової діяльності шляхом використання моделі «екологічної ніші» при наявності у виробничому середовищі ряду шкідливих та небезпечних для людини чинників. Встановлена можливість використання екологічної ніші для математичного моделювання і показників виробничого ризику, але доведено, що необхідно враховувати те, що реакція на один фактор може залежати від впливу іншого з наявних ШНВЧ. Такий підхід дає змогу розробити багатокритеріальну математичну модель визначення виробничого ризику, але треба врахувати зміни параметрів ШНВЧ, що значно ускладнює вирішення задачі, оскільки наслідки дії перевищень у однакових відсотках є різними для всіх ШНВЧ.

Ключові слова: виробниче середовище, ризик, екологічна ніша, гіпер-об'єм, алгоритм.

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Розглянуто питання удосконалення методології визначення ризику трудової діяльності шляхом використання моделі «екологічної ніші». Встановлена можливість використання екологічної ніші для математичного моделювання і показників виробничого ризику, але доведено, що необхідно враховувати те, що реакція на один фактор може залежати від впливу іншого з наявних ШНВЧ. Такий підхід дає змогу розробити багатокритеріальну математичну модель визначення виробничого ризику.

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The issues of improving the methodology for determining the risk of labor activity using the model of «ecological niche» are considered. The possibility of using an ecological niche for mathematical modeling and industrial risk indicators has been established. This approach allows us to develop a multi-criteria mathematical model for determining the production risk.

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