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Development of Methods for the Estimation of Impact of Physical Factors on the Health of Population

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Abstract. **Physical factors (noise, vibration, electromagnetic fields, ionized radiation, etc.) may have a negative influence both on the environment and on the health of population. This study considers the methods and approaches to estimate the impact of physical factors on the health of population and environment. The analysis is performed and the approaches are provided to estimate the influence of physical pollutants on the human health in the Russian Federation. Principles of estimation of the combined impact of physical factors are described. New methods for the estimation of combined impact of physical factors on the functional state of man are suggested. The results of research allow drawing the following general conclusions: complex impact of physical factors on the human health and ecosystems may significantly increase the negative effect.**

Keywords: **physical factors, estimation, impact, method, monitoring**

I. Introduction

Modern city may be considered a sophisticated system with increased impact of negative factors on environment. Some of such factors are physical pollutants: noise, vibration, infrasound, electromagnetic fields, ionization, etc.

Noise level is increasing together with the growth of cities. More than 60% of population of large cities lives in conditions exceeding the acceptable noise limits [3, 5, 8]. Damaging influence of intensive noise on the human health is not restricted only by impact on the ears. It is well known that noise affects the human central and vegetative nervous systems, influencing the human psychological condition etc. The most serious problems are caused by low-frequency acoustic affection [13].

Electromagnetic fields may have a significant negative influence on the human health [3, 6]. The degree of impact of electromagnetic radiation on the humans depends upon the power and the frequency of radiation. For low-frequency radiation (radio waves to visible light), the best-understood effects are those caused by radiation power alone, acting through the effect of simple heating when the radiation is absorbed by the cell. For these thermal effects, the frequency of radiation is important only as it affects radiation penetration into the organism (for example, microwaves penetrate better than infrared). Initially, it was believed that low-frequency fields that were too weak to cause significant heating could not possibly have any biological effect.

Here are some examples of negative influence of only some of physical factors.

To be able to take the required measures for physical pollution reduction it is necessary to develop approaches and methods for the estimation not only of impact of separate physical pollutants, but also of combined impact [6].

This paper aims to study and develop the methods for the estimation of negative impact of physical factors both on the health of population and on the environment.

II. Brief Analysis and Examples of Approaches to Estimate the Influence of Physical Pollutants on the Human Health

In the Russian Federation for the estimation of influence of physical pollutants on the health of population typically different approaches are used:

- the analysis of people's complaints to disturbance of physical pollutants;
- the analysis and comparison of population's sick rate in the database of Russian medical institutions (polyclinics, hospitals, etc.) with measured results of physical pollutants for certain territories;
- people's self-estimation of health state depending on the conditions of protection from physical pollutants, etc.

The following criteria for the determination of health risk posed by physical pollutants are suggested by the authors (Table 1).

As an example of approaches used in Russia to estimate the influence of physical pollutants on the health of population, some results related to the estimation of noise impact on the health of population of Komsomolsky district of Togliatti city will be demonstrated. Investigation of noise impact on the health of population included statistical data analysis of diseases related to the biological impact of noise on the population. The group of such diseases comprises a total of 14 units of diseases: cardio-vascular system, nervous system, gastrointestinal trackt, etc.

Data concerning visits to healthcare facilities for receiving pieces of advice by the population of Komsomolsky district of Togliatti city in a certain time period was used as a source of information about population's sick rate. By using certain procedures (one of which is the method of I.A. Liepa), we together with collaborators from the Institute of Ecology of the Volga Basin of Russian Academy of Sciences have estimated the parameters of equation of the plural linear regression and checked the significance of influence of investigated factors on the sick rate [8]. Taking into account the results of measurements of noise levels in Komsomolsky district of Togliatti city and the primary medical statistical data of the population of Komsomolsky district coming to the medical institutions for advice, it is possible to make a conclusion that there is reliable, statistically significant dependence of the

growth of all 14 units of diseases on the impact of acoustic pollution (Fig. 1).

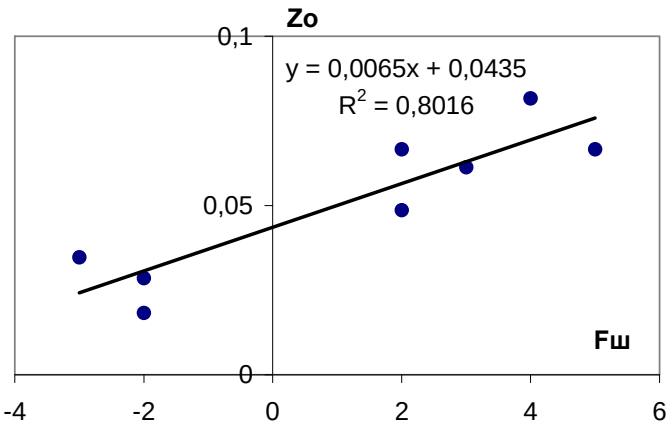

Fig. 1. Dependence of population's sick rate on all health units Z_0, taking into consideration noise impact $F_ш$

TABLE 1

DIFFERENT CONDITIONS (DEGREES OF RISK) OF NOISE LEVELS (DB) FOR DIFFERENT TYPES OF LIFE ACTIVITIES

Types of life activities during 24 hours	Optimal conditions (risk is absent)	Admissible conditions (negligible risk)	Harmful conditions (endurable by means of protective measures)	Damaging conditions (unacceptable risk)
Sleep	15	30	45	60
Rest	35	50	65	80
Work	50	80	100	110

The survey of the population of Komsomolsky district of Togliatti city has been carried out to determine the subjective perception of real noise load. The main purpose of survey has been to reveal the dependence of receptivity to noise affection on the general state of health, age, length of stay, etc. In total, inhabitants of 4 residential houses have been polled (about 100 people): 2 residential houses have been selected with noise levels exceeding normative values, and 2 residential houses with noise levels corresponding to sanitary norms. The number of respondents has been selected proportionally to the number of flats in the above-mentioned residential houses for the purpose of comparison of survey results [12].

The analysis of completed questionnaires leads to the following conclusions:

- the longer the residents of houses situated in the areas of increased noise levels and electromagnetic fields live in the territory of the present study, the worse they appreciate their own living conditions;
- the older the residents are, the more negative their perception of presence of combined acoustic and electromagnetic field pollution;
- the worse the respondents appreciate the state of their own health, the worse (from the point of view of noise impact) they appreciate the comfort of living conditions.

Three types of comfort of living conditions are selected: poor, satisfactory, and good [14].

II. PRINCIPLES OF THE ESTIMATION OF COMBINED IMPACT OF PHYSICAL FACTORS ON THE HEALTH OF POPULATION

When estimating the impact of different physical factors on the health of population, it is necessary to take into consideration the impact of different physical factors in combination with chemical factors. Such kind of impact is considered to be a combined impact.

The existing and common method for the estimation of the impact of different physical factors do not take into account the mutual influence of different physical factors.

In the real conditions, different damaging environmental factors affect the biological objects. Impact of different factors on the organism is interdependent and to a large extent complicates the reaction of the organism.

For the adequate estimation of negative impact of damaging environmental factors, it is necessary to analyse various combinations of factors and their influence on the environment in different situations.

The quantitative estimation of the impact of several factors on the human health makes it possible to determine (Fig. 2):

- **additive** impact, when the effect of exposure is determined by the sum of effects of isolated factors influencing the organism;
- **synergetic** (potential) impact, when the extent of impact of different factors exceeds the additive effect (disproportional amplification of impact is observed);
- **antagonistic** impact, when the impact of combination of different factors is less than the additive impact (attenuation of effects is observed).

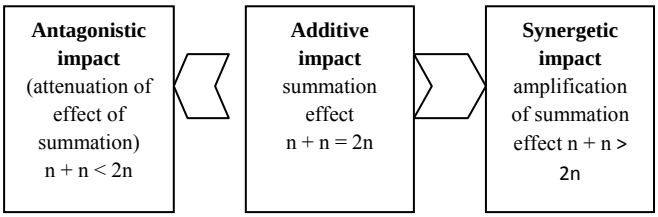

Fig. 2. Different effects of several factors on the human organism

Thus, the combined impact of different factors may have a different effect on the human organism. Damaging impact may be summated, attenuated or amplified (Fig. 2), as well as it may cause variation in the character of influence (e.g., display of carcinogenic effects) [6, 7, 9].

Organism's reaction to the impact of different factors depends on their combination and level. During single impact the additive effect is observed for the substances of narcotic action, irritating gases, etc.

One of the reasons for synergism is inhibition of the processes of biotransformation by one substance or metabolism of the other substance. For example,

the amplification of negative impact has been observed during the combined impact of some pairs of phosphorus organic products.

Antagonism may occur in case of the mutual impact of similar damaging substances on the mechanism of impact.

For the practical purposes, the most important thing to do is to determine the damaging effect of the combination of different factors causing the synergetic impact exceeding the sum of efficiency of impact of separate components. When estimating ecological risks, it is necessary to consider the impact of different combinations of chemical and physical factors on the man and environment.

Also, when estimating ecological risks it is necessary to take into account the effect of summation (addition of different damaging substances in small amounts). Such quantities of substances separately may do not cause any health or ecological problems, but the combination of these substances becomes dangerous due to the mutual amplification of effects (the synergetic impact).

It is important to note that it is also possible to use the summation principle during the calculation of complex impact of polluting substances (penetrating into the human body with air, water and food) on the human health. For practical purposes, it is assumed that the sum of reduced to ПДК (maximum permissible concentration) values of concentrations of polluting substances having summation of impact, should not exceed value "one", that is:

$$C_1 / MAC_1 + C_2/MAC_2 + \ldots + C_n / MAC_n \leq 1, \quad (1)$$

where Ci, C_2 ... Cn – the values of actual concentrations of polluting substances; MAC_1, MAC_2 ... MAC_n – are corresponding values of maximal admissible concentrations (MAC) of substances.

It should be noted that such effects may be a sequence of the combined impact of chemical substances, physical factors, climate conditions, stress impact, etc. For example, the concentration of nitrite that is harmless to rabbits is becoming dangerous due to the increased and also admissible level of ionizing radiation.

Thus, to ensure the ecological safety of population in cities it is necessary to carry out the complex estimation of impact of different physical factors both on the human's health and on the ecosystems. Special attention should be devoted to the study of combined impact of factors of different nature – physical and chemical – on the human organism [1, 2, 6].

III. Development of Methods for the Estimation of Combined Impact of Physical Factors on the Functional State of Man

For the analysis of multi-factor research it is important to select adequate mathematical-statistical method of analysis and of generalization of experimental data. Traditional approach using the multi-factor dispersion analysis and F-criterion of Fisher for the estimation of importance of separate factors and their combination do not allow solving the task of forecasting of functional state of man (FSM) by applying values of parameters of external medium and other factors, participating in its formation. In this case, a researcher needs to use a number of regressive models, describing the interrelation of certain indicator of the functional state of man with the linear or non-linear combination of factors of external environment (FEE):

$$y_i = f(x_1, x_2, \ldots\ldots x_n), \quad (2)$$

where y_i – i-form of values for the estimation of FSM, and $x_1, x_2, \ldots\ldots x_n$ – of FEE.

A number of such equations (depending on the number of used indicators of FSM) may be rather high, and this makes practical application difficult. Moreover, in this case the setting of multidimensional (for totality of FSM) task is observed for the quantitative estimation of system response of the human organism in negative conditions to several one-dimensional tasks. Such an approach is not completely adequate. The most logical seems to be the study of multidimensional system by multidimensional mathematical methods.

During the study of functional state of man, the main models are statistical models of qualitative estimation of the human organism response to factors of life activities.

It is necessary to use the methodology for solving system tasks considering the main characteristics of biomedical information, which is an adequate mean for the generalization and structuring of medical information in the applied biomedical research.

Statistical concepts, including the successive application of factor, canonical, correlation, cluster and discriminant analyses, allow synthesizing the criteria and algorithms for decision making in assessing the functional state of man in the applied biomedical research. Criteria and algorithms for the estimation of the functional state of man allow determining the extent of effort of mechanisms of adaptation of the organism to the factors of vital activity.

Let us consider the results of methodological approach to the determination of integral indicator of the functional state of man (FSM) in coincidence with the integral indicator of physical factor of environment (PFE). As mentioned earlier, it may be carried out on the basis of interrelation of one-dimensional multi-parametric characteristic of human organism response (L_{sost}) and one-dimensional multi-parametric characteristic of external environment (L_{sr}). In this case $L_{sost} = L_{sr}$. On the basis of the application of canonical correlation analysis it is determined that there is a close interrelation of totality of indicators of FSM with totality of parameters of external environment ($\rho = 0.82$; $p < 0.05$). The model that corresponds to this coefficient of canonical correlation may be described in the following equation:

$$-0.19 \cdot y_1 - 0.19 \cdot y_2 - 0.09 \cdot y_3 + 0.06 \cdot y_4 - 0.42 \cdot y_5 - 0.14 \cdot y_6 + 0.13 \cdot y_7 - 0.01 \cdot y_8 - 0.61 \cdot y_9 - 0.76 \cdot y_{10} - 0.61 \cdot y_{11} = 0.38 \cdot x_1 + 0.17 \cdot x_2 - 0.93 \cdot x_3 - 0.08 \cdot x_4; \quad (3)$$

where $x_1 - x_4$ – the factors of medium (noise, vibration, air temperature, lightness);

y_1 – y_4 – the psycho-physiological indicators (tapping test, numerical-letter test etc.);

y_5 – y_8 – the indicators of cardio-respiratory system;

y_9 – y_{11} – the indicators of thermoregulatory reactions.

Coefficients that are used for indicators characterize the factor load and indicate the input of primary indicators into determined multidimensional interrelation of indicators of FSM with PFE. The model was created for normalized values of primary indicators. Its mean values for all selections are equal to 0, and dispersion is equal to 1.

IV. Conclusions

Methods and approaches to estimate the impact of physical factors both on the health of population and on the environment have been described. It has been shown that the physical factors of medium may cause multidirectional reactions of different functional systems of the organism. Complex impact of physical factors may amplify or weaken the system response of the organism. Separate factors of this complex (noise, vibration, temperature of air, lightness etc.) during their interaction may cause multidirectional reactions of different functional systems of the organism.

The input of physical factors into the formation of functional state of man is not equal. It has been shown that in the conditions of urban territory the noise impact on the health of population is more significant than the impact of electromagnetic fields. In the meantime, the results of analysis of noise influence on the population health in combination with other physical factors show the amplification of negative impact and demonstrate the importance of the problem.

The results of research of combined impact of physical factors allow drawing the following general conclusions: complex impact of physical factors on the human health and ecosystems may significantly amplify the negative effect.

In general, the results of research allow forecasting and reducing the negative impact of combination of physical factors on the human health and environment more efficiently.

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