Application of the index-indicator approach for mathematical modeling of the influence of military-technogenic load on the ecological state of the components of the environment in the areas of combat operations

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In order to improve the assessment of the impact of the military-technogenic load on the state of ecologically forming components of the environment, a vector-matrix method of presenting indicators of the state of the abiotic environment of the ecosystem was developed [1]. To determine the indicators of the state of the abiotic component of the ecosystem of the areas of combat operations (CO), the data of standard environmental monitoring are mainly used: field studies, laboratory and express analyzes of pollution of the abiotic component of the environment.

Mathematically, the indicator can be represented by a scalar, a vector chi in a look-alike matrix. This is indicated by the practice of using indicators when considering a wide range of environmental assessment problems [2]. For example, the concentration of a single pollutant can be an indicator, and of course, this value is a scalar. If we are talking about monitoring the process of the spread of a polluting substance, the indicators can be the speed, the direction of the spread of the pollution process, and the change in concentration, that is, the indicator is a vector. Finally, in the study of issues related to the implementation of integral and complex assessments of the ecological state of the areas CO, there is a need to present data in the form of a matrix, each element of which can be either a scalar or a vector. In the future, the mathematical relationships that determine the introduced environmental indicators can be related to the amount of environmental risk and the level of

environmental safety. Accordingly, we will introduce the concept of "simple", "aggregated", "integral" and "complex" indicators into the model of the indicator system [1]. To calculate simple indicators, the values obtained as a result of environmental monitoring are used for the measured, background and maximum permissible concentrations of pollutants in the components of the environment:

$$I_{ci}^{\phi} = \frac{C(a_i^j)_{вим}}{C(a_i^j)_{фон}}$$

$$I_{ci}^{\Gamma} = \frac{C(a_i^j)_{вим}}{C(a_i^j)_{ГДК}}$$

where: $C(a_i^j)_{вим}$- measured concentrations of the *i*-th pollutants of the *j* -th hazard class in the components of the environment;; $C(a_i^j)_{фон}$, $C(a_i^j)_{ГДК}$- background and maximum permissible concentrations of *i*-th ingredients of pollution of environmental components of the *j*-th hazard class; a_i^j - *i*-th pollutant of the jth hazard class; $i = \overline{1,n}$- the index of the relevant pollutant; $j = 1 \div 4$- hazard class of the relevant pollutant.

To calculate the aggregated indicators, the values of the measured and background concentrations of pollutants in ecologically forming components of the environment are used:

$$I_{agr}^{j} = \begin{cases} \frac{1}{N_{\Sigma}^{j}} \cdot \sum_{i=1}^{N_{\Sigma}^{j}} \frac{C(a_i^j)_{вим} - C(a_i^j)_{фон}}{C(a_i^j)_{фон}} \cdot \eta_i, & \forall C(a_i^j)_{вим} > C(a_i^j)_{фон}; \\ 0, & \forall C(a_i^j)_{вим} < C(a_i^j)_{фон}, \end{cases}$$

where η_i- weighting coefficients for pollutants determined by experts taking into account their biochemical activity, toxicity, carcinogenicity, migration ability, bioaccumulation, ability to accumulate; N_{Σ}^{j}- the number of pollutants of the *j*-th hazard class.

The generalized aggregate indicator of pollution by hazard classes and environment-forming factors can be presented in the form of a matrix:

$$I_{agr} = \begin{bmatrix} I_A^1 & I_A^2 & I_A^3 & I_A^4 \\ I_{L^p}^1 & I_{L^p}^2 & I_{L^p}^3 & I_{L^p}^4 \\ I_{L^g}^1 & I_{L^g}^2 & I_{L^g}^3 & I_{L^g}^4 \\ I_G^1 & I_G^2 & I_G^3 & I_G^4 \end{bmatrix}.$$

According to the results of the analytical studies, based on the analysis of the composition of typical pollutants according to the corresponding classes of danger for the components of the abiotic environment, an information portrait of chemical pollution of the CO management area or its functional zone is compiled in the form of a pollutant matrix

$$I_{agr}^{inf} = \begin{bmatrix} N_{\Sigma A}^1 & N_{\Sigma A}^2 & N_{\Sigma A}^3 & N_{\Sigma A}^4 \\ N_{\Sigma L^p}^1 & N_{\Sigma L^p}^2 & N_{\Sigma L^p}^3 & N_{\Sigma L^p}^4 \\ N_{\Sigma L^g}^1 & N_{\Sigma L^g}^2 & N_{\Sigma L^g}^3 & N_{\Sigma L^g}^4 \\ N_{\Sigma G}^1 & N_{\Sigma G}^2 & N_{\Sigma G}^3 & N_{\Sigma G}^4 \end{bmatrix}.$$

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