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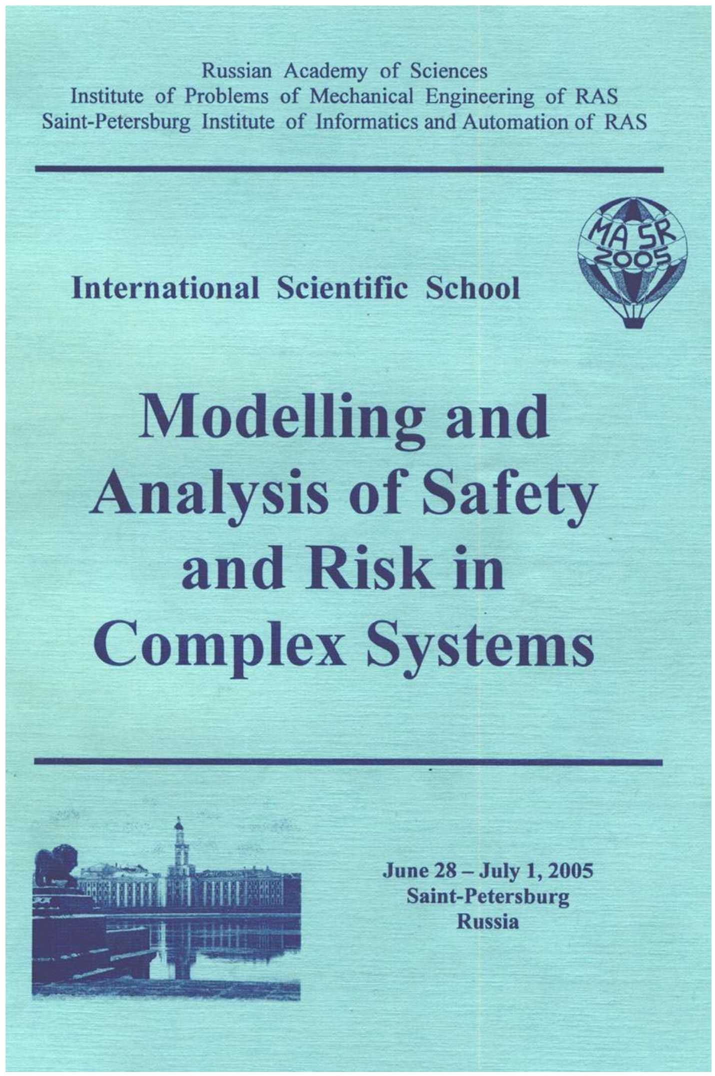

EVALUATION OF HYDROECOSYSTEM TECHNOGENIC DAMAGE ON THE BASIS OF ENVIRONMENTAL RISK ANALYSIS

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The method of evaluation and forecast of hydroecosystem technogenic damage, based on environmental risk analysis is suggested. Ways of possible technogenic impacts on water ecosystem and probable variants of technogenic succession are defined. The environmental damage is calculated as the sum of mathematical expectations of damage from realization of alternative scripts of environmentally hazardous events.

Environmental risk; environmental damage; technogenic impact; hydroecosystem; environmental safety management

Problem of correct definition and forecast of environmental damage from the constructing and operating industrial objects is the one of the most topical tasks of modern hydroecology. It is obvious, that development of environmentally hazardous events during construction and operation of industrial objects in normal mode and, in emergency condition, cannot be accurately determined and has probabilistic nature. Accordingly, calculation of technogenic hydroenvironmental damage should be based on results of environmental risk analysis. However, available methods of technogenic environmental damage forecast completely exclude the risk analysis. Instead of this, concrete values of variables are co-ordinated: (1) external factors values → (2) change of environment characteristics values → (3) corresponding environmental damage in natural expression → (4) environmental damage in cost expression [1, 2, etc.]. Methods of technological risk analysis [3] also cannot be applied for decision of this task because of obvious essential differences between the technical refusal processes and environment technogenic impacts. Operation of industrial object even in normal, accident-free mode causes some damage to all environmental components. Consequently, the development of adequate method of technogenic damage evaluation on the basis of environmental risk analysis is needed.

The suggested method of evaluation of water ecosystem environmental risk from construction, operation and reconstruction of industrial objects is briefly amounted to the following actions.

Initial water ecosystem characteristics, authentically changed investigated technogenic impact are defined. All possible ways of direct and indirect (connected with hydroecosystem succession) impacts of object on water ecosystem components during its construction and operation are revealed. In doing so, large variety of possible forms of development technogenic eutrophication at various combination of impact characteristics and hydroecosystem characteristics is taken into account as completely as possible [4].

The tree of possible environmentally hazard events connected to construction and operation of object is created. Every script takes into account probability ***(p)*** and full value of damage for recipients of influence in natural expression ***(U)***. The probability of realization of each independent script of environmentally hazard events from *n* potentially possible scripts ***(p_i)*** is multiplicatively defined by the following formula:

$$p_i = \prod_{j=1}^{k} p_{ij} , \qquad (1)$$

where p_{ij} - probability of realization of the i-th script from *k* subsequental events.

Thus, in correct account and analysis of possible alternative scripts of development of environmentally hazard events:

$$\sum_{i=1}^{n} p_i = \sum_{i=1}^{n} \prod_{j=1}^{k} p_{ij} = 1 \quad (2)$$

Expected damage R in cost expression is calculated as the sum of mathematical expectations of damage from realization of alternative scripts of environmentally hazard events, on the equation:

$$R = \sum_{i=1}^{n} R_i = \sum_{i=1}^{n} \left(\xi_i \times U_i \times p_i \right) = \sum_{i=1}^{n} \left(\xi_i \times U_i \times \prod_{j=1}^{k} p_{ij} \right), \quad (3)$$

where:

n – quantity of analysed alternative scripts of environmentally hazard events caused by object impact;

R_i – probable environmental damage from realization i-th script in cost expression;

U_i – full value environmental damage in natural expression;

ξ_i – coefficient for conversion of damage in natural expression to cost expression with regard to concrete composition and structure of final recipients of influence.

There are many situations when, according to the script, the damage to one component of environment completely or partially causes damage to other component, and further division of alternative scripts becomes impossible. Thus, the resulting value of damage for both components is not additive and can be defined as follows:

- if the damage to the first component is completely shown in the damage to the second component, only the second (greater) parameter is taken into account.
- if the damage to the first component is only partially shown in damage to the second component, resulting value of damage defines as sum of damage values for both components in their interaction, and of residual damage values for each components separately.

The map of spatial distribution of environmental risk in cost expression is made. The zone of expected authentic impact of object on environment is allocated. This zone includes a land or water area, where level of environmental risk authentically exceeds background level. If there are several alternative design decisions, for each of them the common values of expected environmental-and-economic damage are defined. The decision, connected to the minimal environmental risk and the least relation between cumulative environmental costs and prevented environmental damage, is preferable.

The different examples of environmental risk formation are analyzed: hydroconstruction, operation of mining and pulp-and-paper industry enterprises, power stations, construction and operation of major pipelines and other situations of technogenic impacts on environment [4].

Thus, some common specifics of distribution of various water ecosystem characteristic values are showed up. Symmetrical and moderately asymmetrical (normal, Maxwell etc.) distributions rarely give an acceptable description of histograms. It concerned only some initial factors or initiating events. In the further chain of events asymmetry of distributions essentially and regularly grew. In some scripts, lognormal distribution yielded to even more asymmetric distributions (exponential, Pareto). However, for majority of characteristics, used at technogenic environmental risk analysis, the most correct description of histograms still gave lognormal distribution. So, this type of distribution proved to be unique.

The situation of technogenic impact on the Plussa River ecosystem (Leningrad region) can be an example. We will be limited to evaluation of present damage from impact of Joint-stock Company "Leningradslanets" on the Plussa River ecosystem and expected damage after construction and starting of operation of mine water purification plant. The analysis of technogenic environmental risk has allowed to define environmental damage and evaluate its expected change after realization of this environmental protection measure.

The levels of present and expected multifactorial loading on river ecosystem was evaluated by original "isobolic" parameter Y (it expresses the rate of excess by any complex impact of its maximum permissible level for biota [4] (example for two sample station - in figure 1)).

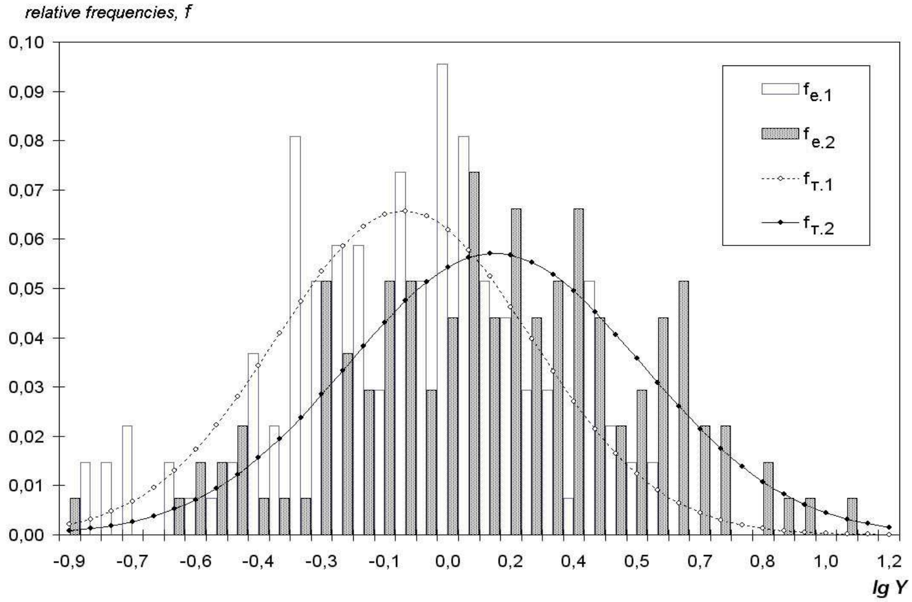

Fig. 1. Examples of isobolic parameter (***Y***) values histograms on two sample stations in river technogenic eutrophication ($f_{e.1}$ and $f_{e.2}$ - empirical relative frequency, $f_{T.1}$ and $f_{T.2}$ - theoretical relative frequency for lognormal distribution).

On fig. 2 histograms of calculated values of environmental damage before and after suggested environmental measure are assotiated. Distributions have lognormal character. The lognormal distribution modal value after environmental measure introduction will essentially displace in area of smaller values.

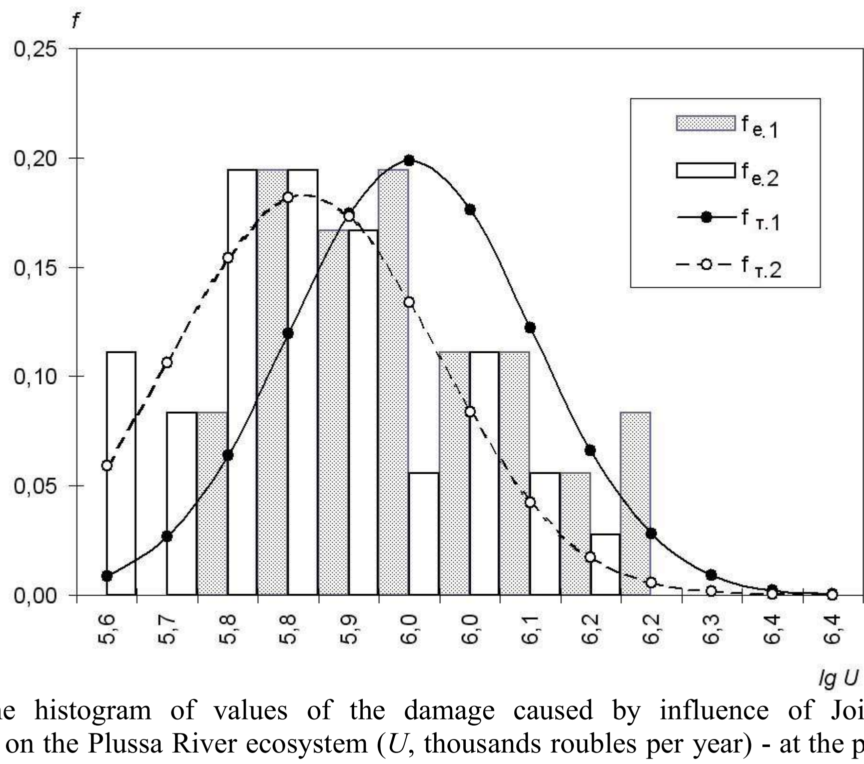

Fig. 2. The histogram of values of the damage caused by influence of Joint-stock Company "Leningradslanets" on the Plussa River ecosystem (*U*, thousands roubles per year) - at the present time (1) and expected after realization recommended measure (2).

Mentioned above is proved by figure 3. Fig. 3 reflectes the expected change of relative frequencies after environmental measure realization *(Δf)* depending on the logarithm of fishery damage values. It is demonstrated, that the relative frequency value is naturally displaced to the area of smaller values.

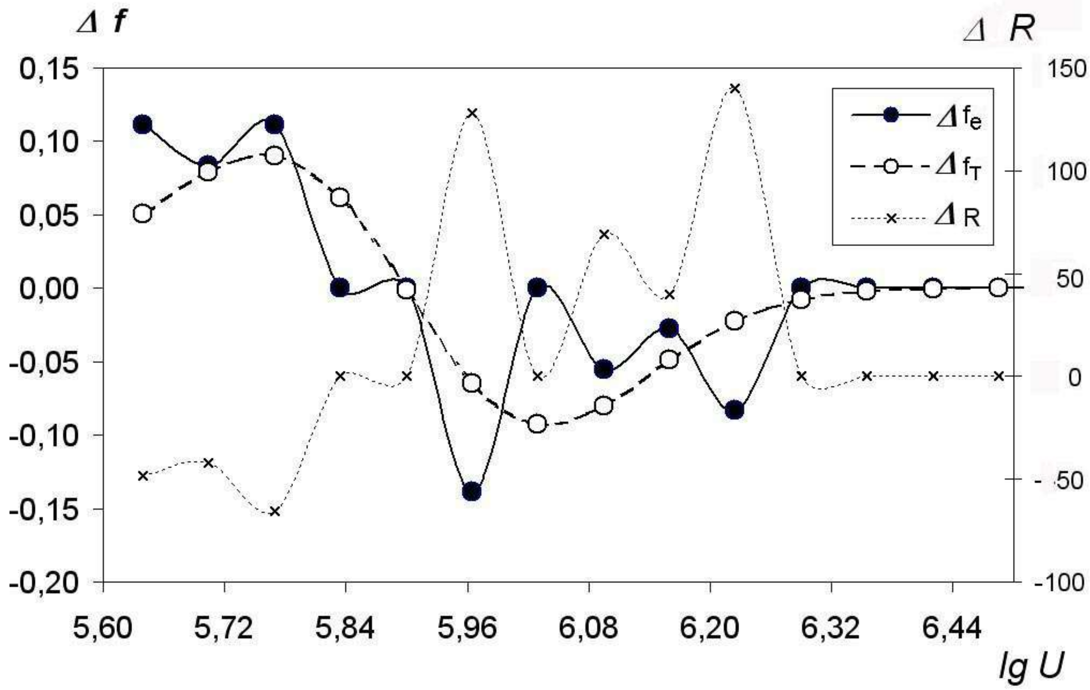

Fig. 3. Expected change of relative frequencies (Δf) of various classes of environmental damage (*U,* thousand ruble per year) and mathematical expectation of the prevented environmental damage (Δ*R*, thousand ruble per year) after realization of suggested environmental measure (*Un*) (Δf_e and Δf_t - empirical and theoretical change of relative frequencies).

Rated (theoretical) frequencies of lognormal distributions:

$$F = \frac{N \times c}{\sigma \times \sqrt{2\pi}} \times e^{-0.5\times\left(\frac{\lg U - \overline{\lg U}}{\sigma}\right)^2}, \qquad (4)$$

Where N – quantity of scripts, c - class interval; explained variance of the general dispersion of empirical relative frequencies - 92 % (1) and 89 % (2); Kolmogorov's criteria - 0.35 and 0.49 accordingly; N = 250000.

Rated value of present-day environmental damage caused by influence of the enterprise on the Plussa River ecosystem amount up 970 thousand roubles per year. Value of the damage, expected after realization of environmental measure - 750 thousand roubles per year. In this case, the expected size of prevented damage will be about 220 thousand roubles per year. Thus, the distribution of prevented fishery damage possible values at various succession scripts also comes nearer to lognormal (fig. 4).

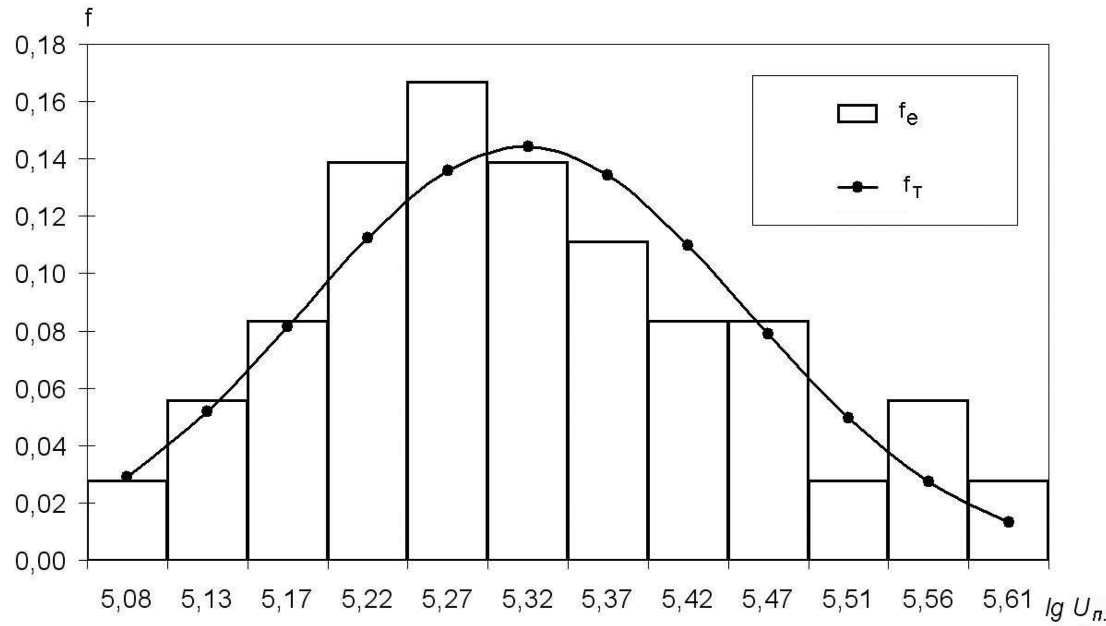

Fig. 4. The histogram of prevented environmental damage values, expected from realization of suggested environmental measure (*Un*, thousand ruble per year). Theoretical frequencies correspond to lognormal distribution, explained variance of the general dispersion of empirical relative frequencies – 95 %; Kolmogorov's criteria - 0.37. (f_e and f_t - empirical and theoretical relative frequencies).

The above method allows to make a forecast of environmental damage from impact on water objects, caused by the enterprises in process of construction and operating. It provides the substantial increase of estimation result accuracy because of the adequate account of probable scripts of consecutive ecosystem condition changes.

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