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IMPROVEMENT OF METHOD OF ASSESSMENT OF ENVIRONMENTAL CONDITION OF TERRITORIES ADJOINED WITH ENVIRONMENTALLY DANGEROUS TECHNOGENIC OBJECTS

Assessment of environmental condition of territories adjoined with environmentally dangerous technogenic objects has to be accomplished considering complex multifactor environmental impacts. The process of the territory ecosystem functioning under the influence of environmentally dangerous technogenic object. It is found that territory' environmental condition may be fully and uniquely displayed with its ecosystem response on negative impact. Significant responses of ecosystem are those characterizing degree of degradation processes in it. Two of responses calculated on the surface area and spread speed of degradation processes over the territory are resumptive from the point of assessment of the whole complex of technogenic object' negative impacts. It is also found that ecosystem response on negative impact may be expressed as array of 36 indexes of energy flow through ecosystem according levels of its trophic structure. To narrow variety of significant indexes I have separated two of them which allow operative assessment of the territory' environmental condition. They are productiveness of the first trophic level species (plants) and biomass amount of the forth trophic level species (supreme predators). The last index may be simplified by expressing it with the number of animals in corresponding species population. I have developed new criterion of the territory' environmental condition assessment – environmental reserve criterion. According to mentioned criterion transformation of the critical environmental condition of the territory into catastrophic is designated with obtainment of zero value by environmental reserve level index. Further development of catastrophic ecosystem degradation is characterized with its values less than zero. Developed criterion takes into account both interrelations between elements of natural surrounding and result of impact of environmentally dangerous object on these elements. Implementation of new environmental reserve criterion makes the method of territories' environmental condition assessment applicable for assessment of impact of any environmentally dangerous technogenic object same as for operative environmental safety control.

Keywords: environmentally dangerous technogenic object; environmental reserve; degradation degree.

1. Problem statement.

Significant anthropogenic and technogenic overloading of the territory of any state by means of pollution of atmospheric air [1, 2] and soil, especially with heavy metals [3], and also by means of waste accumulation [4, 5] poses a threat for national interests and national safety. It stimulates scientists of the whole worlds to find the ways for environmental state improvement using cheap and effective methods and technological solutions [6–8]. Technogenic activity leads to increasing of risks of occurrence of technogenic and natural extreme situations. Thus, investigations on assessment of civil protection units' readiness to actions during extreme situations are taken [9, 10].

Consequently, the most necessary directions of state policy of any country include:

– application of organizational, economical, engineering and other measures to decrease risks of extreme situations occurrence down to allowable levels;

– increase of environmental safety levels up to the requirements of norms and standards used in corresponding spheres.

Technogenic objects created for solid household wastes accumulation are powerful sources of both natural environment pollution and extreme situations. Because of fire occurrence at such objects they register sharp increase of level of environmental danger for the territory adjoined to them. It is connected with formation of toxic burning products and elution of toxic pollutants from wastes with water used for fire extinguishing. In case of excessive usage of water catastrophic events may take place, such as landslide, flooding, etc. Despite of existence of environmentally safe technologies developed for solid household wastes utilization [11, 12] producing energy raw materials [4, 13] this problem is topical for the most countries of the world [14–16].

According to statistical data collected by the World Fire Statistics Center of the International Association of Fire and Rescue Service [17], in most of the countries fires connected with waste inflammation take more than 15 % of total amount of registered fires (see table 1).

It should be noted that the problem of fires at technogenic objects for wastes accumulation and storage is sharp. It is topical both for the countries with high economy level (USA, France, Italy, Sweden, etc.) and for developing ones (Bulgaria, Estonia, Latvia, Lithuania, Ukraine, etc.). This problem is the most sharp for the countries of Eastern Europe.

Thus, assessment of environmental condition of the territories adjoined to environmentally dangerous technogenic objects is a topical task. Assessment has to be accomplished taking into account complex multifactor environmental impacts. Simultaneously we must provide the opportunity for dynamic operative environmental safety control.

Table 1 – Waste storage fires registered in certain countries in years 2012 – 2016 [17]

Country	Amount of waste storage fires / rate in total amount of registered fires				
	Year				
	2012	2013	2014	2015	2016
Bulgaria	6287 / 13,7 %	6125 / 18,6 %	4868 / 21,0 %	6348 / 21,0 %	6672 / 17,9 %
Great Britain	–	2210 / 1,4 %	–	–	–
Greece	1639 / 4,7 %	1580 / 5,6 %	–	–	–
Denmark	1824 / 12,3 %	–	–	–	–
Estonia	1424 / 28,6 %	1874 / 32,1 %	1819 / 26,5 %	1722 / 30,9 %	1600 / 31,6 %
Italy	40695 / 16,9 %	–	–	–	–
Cyprus	459 / 6,8 %	519 / 6,0 %	–	–	–
Latvia	429 / 4,9 %	2316 / 24,6 %	2316 / 23,6 %	1473 / 13,4 %	1099 / 11,1 %
Lithuania	2805 / 24,9 %	2792 / 21,9 %	2920 / 21,9 %	2614 / 21,8 %	2211 / 22,0 %
Poland	27012 / 14,7 %	23961 / 19,0 %	3100 / 2,1 %	24203 / 13,1 %	–
Romania	7263 / 18,6 %	–	–	2554 / 11,4 %	2861 / 10,3 %
Singapore	–	433 / 10,5 %	–	–	96 / 2,3 %
Slovenia	523 / 9,4 %	449 / 12,1 %	–	531 / 7,6 %	–
USA	–	158000 / 12,7 %	157500 / 12,1 %	163000 / 12,1 %	172000 / 12,8 %
Hungary	2395 / 6,5 %	1243 / 4,3 %	1014 / 5,2 %	1168 / 5,5 %	1043 / 5,9 %
Ukraine	–	–	24723 / 34,9 %	–	–
Finland	324 / 2,7 %	850 / 6,3 %	–	730 / 6,5 %	715 / 5,9 %
France	–	35051 / 12,4 %	–	–	–
Croatia	254 / 2,3 %	–	1454 / 19,9 %	2279 / 18,7 %	1929 / 17,3 %
Czech Republic	–	5311 / 31,0 %	2656 / 15,3 %	5266 / 26,1 %	4438 / 27,3 %
Sweden	2334 / 10,3 %	2182 / 8,6 %	–	2305 / 10,1 %	–

Note. Sign «–» marks years not supplied with statistical data for certain country.

2. Analysis of the recent researches and publications.

When investigators resolve problems of methodology development for assessment of territories' environmental condition, they generally use two basic approaches: expert and calculation ones. Expert approach means formulation of the assessment results based on conclusions formed by the group of experts after studying of big amounts of data.

For example, when the Living Planet Report [18] was prepared, assessment and forecasting of the environmental condition was carried out using indexes of environmental footprint and living planet index. Herein they used scenarios of environmental changes development based on conclusions of the United Nations experts. In the work [19] they have also used expert responses to determine soil degradation types and build corresponding maps.

The lack of expert approach is in not taking into account those limiting values of indexes, which are established in normative documents. Therefore, they lose opportunity to establish precise quantitative values corresponding to the moment of transformation of the environmental condition from one danger level to another. In particular, debriefing results represented in work [20] show that almost 80 % of practicing experts on environmental condition assessment find uncertainty in expert evaluations with insufficient disclosure of it.

To overcome the lacks of expert approach they use different ways of certain generalizing indexes determination by means of summation of the assessments obtained on separate indexes. As a rule, they use weight coefficients for this purpose. For example, in work [21] they combined different environmental impacts into unified index of the building life cycle assessment using weight coefficients with internal normalization.

To determine waste accumulation locations in study [22] they have proposed the method based on evaluation of the weighted linear combination of the environmental impact factors. Herein they were determining weight coefficients of certain factors by means analytical hierarchy process application.

To control the environment in work [23] they have developed the combined method of the environmental condition indexes evaluation. The mentioned method is a result of the synthesis of three evaluation methods:

– Multiple Lines of Evidence method using indexes of assessment of fish population behavior [24];

– Conceptual Model Diagrams method where results of simulation of environmental impact effects are represented in graphical form [25];

– Eco Evidence method where results are obtained by means of computer simulation of environmental impacts [26].

In work [27] the author has proposed to form integral calculated assessment of the territory environmental condition using points scale. Herein the integral assessment is evaluated as an arithmetical mean of separate assessments calculated with the selected indicator indexes.

They may also use the manufacturing process parameters as a basis of the unified index calculation. For example, in work [28] they have proposed to calculate MIPS-index for assessment of the environmental friendliness of the natural and technogenic complexes by the water component of the

natural environment. The mentioned index is a reduced sum of assessments of each separate pollution. Each of separate assessments takes into account impact intensity and concentration of the corresponding substance in environment.

As you may see, variability of the calculation methods is high enough. However, unfortunately the calculation results obtained with the represented methods may be applied only for comparison of different territories with each other. Thus, such methods are not applicable for determination of the absolute indexes of the environmental condition.

It has to be emphasized, that the represented set of methods does not include the unified approach for determination of the environmental condition based on the level of negative changes in ecosystems. For example, in the EU Water Framework Directive [29] they have subdivided territory' environmental conditions in the following types: high, good, moderate, poor, and bad ones. This approach defines environmental condition basing on the level of satisfaction of the normative requirements for the environment quality. In contrast to this in work [30] the author has proposed to classify territory' environmental conditions according to the degree of ecosystem degradation. This classification contains such types of conditions: conditionally favorable (prosperous), satisfactory, strained (pre-critical), critical (or crisis), and catastrophic ones. In work [31] they have specified interrelation between critical and crisis condition of the territory. Herein crisis condition is equalized with the boundary one characterized by the environmental extreme situation occurrence. Then the catastrophic condition contains deep irreversible changes in ecosystem.

Today they also use approaches for assessment of territory' environmental condition, which differ with the set of indexes used for evaluation. For example, in work [27] the integral criterion is calculated on indexes of environment components condition determined on the official reports based on The UN European Economic Commission Directive [32]. The lack of such approach is that the used indexes are limited with the most important ones only. It allows defining the main trends of the territory condition development, finding sources and consequences of negative environmental impacts, and assessing effectiveness of protective measures in generalized form only.

So, the represented in modern studies approaches for resolution of the problem of the territory' environmental condition assessment are mostly directed on generalized assessment and forecasting. Therefore, their practical application for dynamic operative control of environmental safety is substantially complicated.

Since the real conditions of ecosystem functioning are characterized with the impact of the complex of negative factors, assessment of the result of such impact must be based on the formed dynamic models of the environment response occurrence. Then we have to investigate the environmental processes as an integrated complex of chemical, biological, geological, technogenic processes, etc. We have to evaluate processes taking place in ecosystems of different levels simultaneously. And we have to analyze such processes as open systems using synergistic approach [33]. They have successfully used such approach for population ecology investigations. Its implementation in other spheres of environmental sciences is also topical. Obviously, the extended set of criteria indexes has to be defined using environmental approach. Such approach is in investigation of interrelations and interconnections of the ecosystem with its functional environment using environmental indicators, indexes and factors [34].

Separate application of different approaches for control of the negative impact on the atmosphere, hydrosphere and lithosphere does not allow providing complex environmental protection. The mentioned lack is connected with not taking interrelations between different natural environment components into account. This interrelation is represented with the migration of pollutants between these components. Then they do not take into account the secondary pollutions of the environment. For example, they do not evaluate precipitation of dust and soot from atmospheric emissions with the rain, pollutants transfer from wastewater into the soil of territories adjoined to ponds, etc.

Such approach narrows the task of environmental protection down to implementation measures on decrease of separate indexes by means of negative impact factors redistribution between natural environment components. In fact, in such case the total level of negative impact practically does not decrease. So, the problem of improvement of existing methods of assessment of environmental condition of the territories adjoined to environmentally dangerous technogenic objects same as development of the new ones is topical. Yet the method developed must be based on the unified approach to assessment taking into account all interrelations between natural environment components.

3. Statement of the problem and its solution.

The aim of investigation is to improve the method of assessment of environmental condition of territories adjoined with environmentally dangerous technogenic objects. To obtain the aim the following tasks were stated and resolved:

– to carry out the analysis of the peculiarities of the ecosystem functioning for the territory adjoined to environmentally dangerous technogenic object under the negative impact;

– to develop the criterion of assessment of environmental condition for the territory adjoined to environmentally dangerous technogenic object, which takes into account all interrelations between environment components and result of the object impact on these components.

3.1. Materials and methods of investigation of dangerous technogenic object impact on natural environment.

The basis of investigation is the method of evaluation of safety level of waste storage place represented in [35]. The essence of this method is in simulation modeling of functioning of environmentally dangerous technogenic object with step-by-step evaluation of safety level on

certain set of criteria. The mentioned criteria set is formed in correspondence with the requirements of normative documents to define safe conditions of the object maintenance.

The basis for improvement of the method is the application of the environmental reserve criterion stated as "the criterion of the territory possession of sufficient capacity to perceive external factors of negative impact without transition into catastrophic condition". This statement we represent in the following formalized way:

$$\chi^{\rho} = \rho\left(\overline{F}\right):\ \chi^{\rho} \geq 0\,, \qquad (1)$$

where $\overline{F}$ – the value of the certain factor of negative impact on natural environment; ρ – the index of the environmental reserve level estimated with the following formula

$$\rho = 1 - \overline{\varepsilon}\,, \qquad (2)$$

where $\overline{\varepsilon}$ – the reduced value of the ecosystem response on negative external impact.

Due to complex character of ecosystem reaction on different negative factors impact the evaluation of the territory' environmental condition should be accomplished by means of comparison of the object' environmental conditions with certain norms taking into account potentially possible external impacts. I have chosen the degree of degradation of ecosystem of the territory adjoined to investigated object as an index describing the level of the object negative impact.

The main component of the ecosystem is biocenosis. It is formed of biological species of vegetable and animal world united by the common aim of functioning – survival. Thus to find the quantitative characteristics of degradation processes in ecosystems I have investigated the structural-functional organization of ecosystem and its biocenosis.

The universal model of environmental energy flow [36] is used when forming the environmental reserve criterion for quantitative description of ecosystem processes.

3.2. Results of analysis of the ecosystem functioning under the impact of dangerous technogenic object.

In ecosystem vegetation accomplishes function of the Sun energy accumulation by means of photosynthesis. This way plants create primary reserve of organic substances. Thus vegetation is the first to reflect any changes in environmental condition of the territory adjoined to environmentally dangerous technogenic object. Changes of plant cover occur because of mechanical or chemical impacts. Objective assessment of such changes may be formed only in comparison with the natural condition of ecosystem. This natural condition is defined with equalized values of ecosystem characteristics. For investigation they choose certain species-indicators displaying reaction on impact. To form the conclusion on assessment results they use some generally approved limited values of indexes for comparison.

Animals later use amounts of organic substances accumulated by vegetation species. Today they characterize condition of the animal world with a wide range of criteria established on different levels of its structure. As quantitative indexes they use both generalized characteristics of the whole zoocenosis and separated parameters of certain species population functioning.

For any investigated territory, its ecosystem community forms unified trophic structure combined of all species of plants and animals. In general case this structure may be divided in four trophic levels. Each of these levels is formed by organisms getting energy from the Sun by means of consecutive transformation through the same number of trophic levels [36]:

1. level of producers (I) is formed with all species of plants;
2. level of primary consumers (II) is held by the species of herbivores fed directly by the plants;
3. level of secondary consumers (III) is formed by the species of primary predators fed by herbivores;
4. level of tertiary consumers (IV) is taken by species of secondary (supreme) predators.

Such classification concerns mostly to those functions performed by the species in ecosystem. In many cases one and same biological species may take some trophic level for functioning consuming both plants (second level) and animals (third and/or fourth levels). Significant part of the energy accumulated on previous level of trophic structure is lost with each transfer to the next level. Thus, quantities of populations of plants and supreme predators differ significantly.

Species of the first trophic level support the full structure filling it with organic substance. Correspondingly, species of the fourth trophic level actually regulate whole ecosystem due to their small quantity. Even little decrease of their population amount may become a threat for preservation of current condition of ecosystem as a whole. Additionally, small quantity of supreme predators allows finding the amount of accumulated biomass by simple calculation of the species number.

Each trophic level in any condition of ecosystem may be estimated quantitatively by the amount of biomass B accumulated at it, together with the set of its energy exchange characteristics evaluated for certain fixed time interval:

– amount of energy absorbed by trophic level I;
– amount of energy not used by trophic level NU;
– amount of energy assimilated by trophic level A;
– amount of energy productivity of trophic level P;
– total amount of energy used by trophic level for respiration R;
– amount of stored energy accumulated by trophic level S;
– amount of energy emitted by the species of trophic level E;
– amount of biological growth of species of trophic level G.

For each of these characteristics there is equilibrium value corresponding to natural condition of ecosystem. Condition of each trophic level in ecosystem may be described with the set of nine indexes of energy flow. We may establish interrelation of these indexes using universal model of environmental energy flow [36] in following formal representation:

$$\Theta^i = \left\{B^i, I^i, NU^i, A^i, P^i, R^i, S^i, E^i, G^i\right\}, i \in \{I, II, III, IV\}; \quad (3)$$

$$\varphi_I{}^i : B^i \to \left\{I^i \to A^i \to P^i\right\}, i \in \{I, II, III, IV\}; \quad (4)$$

$$\varphi_P{}^i : \left\{I^i \to A^i \to P^i\right\} = \begin{cases} A^i = I^i - NU^i, \\ P^i = A^i - R^i, \\ P^i = G^i + S^i + E^i, \end{cases} \quad i \in \{I, II, III, IV\}; \quad (5)$$

$$\varphi_B{}^i : \left\{P^i \to G^i\right\} \to B^i, i \in \{I, II, III, IV\}. \quad (6)$$

Total number of significant indexes to make mathematically full description of the territory' environmental condition is 36. Connection between the ecosystem energy flow indexes mentioned above may be represented in the following formal way:

$$\Theta = \left\{\Theta^I, \Theta^{II}, \Theta^{III}, \Theta^{IV}\right\}; \quad (7)$$

$$\varphi_\Theta : \left\{\Theta^I \to \Theta^{II} \to \Theta^{III} \to \Theta^{IV}\right\} \to \Theta^I. \quad (8)$$

Graphical representation of this connection is shown at figure 1.

Response of ecosystem on negative impact being formalized with the array Θ will fully and uniquely characterize environmental condition of the territory adjoined to environmentally dangerous technogenic object. However experimental evaluation of the most of these indexes is significantly complicated because of the necessity to carry out the big amount of the field studies over the wide territory.

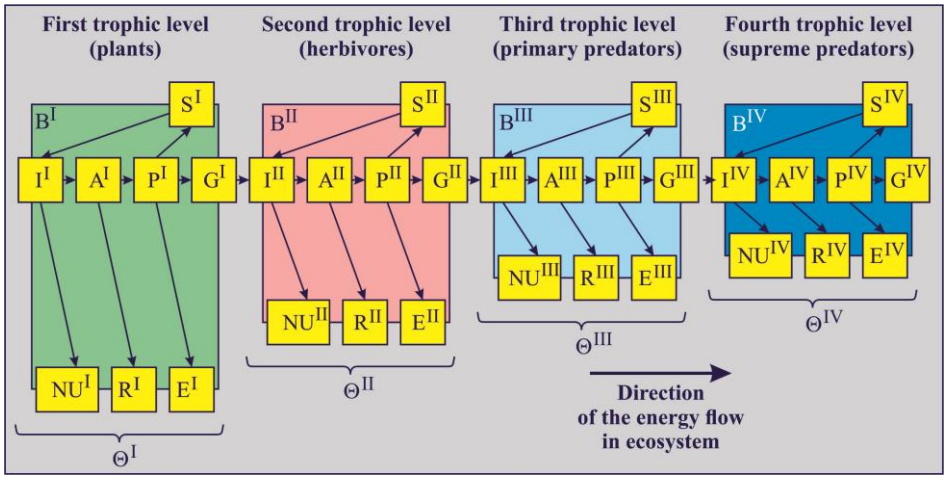

Figure 1 – Significant indexes of the ecosystem energy flow

3.3. Development of the criterion of assessment of the territory' environmental condition on the result of impact of dangerous technogenic object on ecosystem.

For realization of criterion of assessment of the territory environmental condition significant responses of ecosystem were selected.Two indexes were taken as generalized responses of ecosystem on negative impact of dangerous technogenic object: surface area S_d and spread speed v_d of degradation processes

$$\varepsilon_S = S_d; \quad (9)$$

$$\varepsilon_v = v_d. \quad (10)$$

The advantages of the given indexes for assessment of the territory' environmental condition are their sufficient simplicity and proficiency of measuring methods. For operative evaluation of the surface area S_d value it is expedient to use method based on analysis of materials of the remote sensing of the Earth [37].

After establishing allowable limits for selected indexes – $[S_d]$ and $[v_d]$ correspondingly – ecosystem responses were formalized in reduced way with following formulas:

$$\overline{\varepsilon}_S = \frac{S_d}{[S_d]}; \quad (11)$$

$$\overline{\varepsilon}_v = \frac{v_d}{[v_d]}. \quad (12)$$

Responses calculated with formulas (11), (12) are fully suitable for preliminary assessment of the territory' environmental condition. These responses are generalized from the point of assessment of the whole complex of negative impacts of technogenic object. In addition these responses may be evaluated with the modern methods. The disadvantage of these responses is the practical impossibility of precise registration of local differentiation of degradation processes for separate areas. Thus indexes $\overline{\varepsilon}_S$ and $\overline{\varepsilon}_v$ are not fully applicable for precise evaluation of environmental condition with the detailed forecasting of future degradation process development.

Taking into account specificity of ecosystem trophic levels functioning the most significant and available for measuring are two of the components of the array Θ:

– productivity of species of first trophic level P^I;

– amount of biomass of species of fourth trophic level B^{IV}, which may be reduced down to the number of animals in population N^{IV}.

After selection of characteristic species-indicators of first and fourth trophic levels for investigated ecosystem, we may evaluate two responses of it. They are deviation of productivity of species of first trophic level P^I from its equilibrium value $\left[P^I\right]$

$$\varepsilon_P = \left| P^I - \left[P^I\right] \right|, \qquad (13)$$

and deviation of population number of species of fourth trophic level N^{IV} from its equilibrium value $\left[N^{IV}\right]$

$$\varepsilon_N = \left| N^{IV} - \left[N^{IV}\right] \right|. \qquad (14)$$

In reduced form these responses of ecosystem will look like

$$\overline{\varepsilon}_P = \frac{\left| P^I - \left[P^I\right] \right|}{\left[P^I\right]}; \qquad (15)$$

$$\overline{\varepsilon}_N = \frac{\left| N^{IV} - \left[N^{IV}\right] \right|}{\left[N^{IV}\right]}. \qquad (16)$$

Using ecosystem responses indexes evaluated on formulas (11), (12) and (15), (16), values of ecosystem environmental reserve level index were found with formula (2) on four established characteristics including:

$$\rho: \begin{cases} \rho_S = 1 - \overline{\varepsilon}_S; \\ \rho_v = 1 - \overline{\varepsilon}_v; \\ \rho_P = 1 - \overline{\varepsilon}_P; \\ \rho_N = 1 - \overline{\varepsilon}_N. \end{cases} \qquad (17)$$

Using the last result with formula (1) the developed criterion of environmental reserve was represented in following generalized formal way:

$$\chi^\rho: \begin{cases} \rho_S\left(\overline{F}\right) \geq 0; \\ \rho_v\left(\overline{F}\right) \geq 0; \\ \rho_P\left(\overline{F}\right) \geq 0; \\ \rho_N\left(\overline{F}\right) \geq 0. \end{cases} \qquad (18)$$

Improvement of method of evaluation of safety level of waste accumulation location by means of introduction of new criterion of environmental reserve makes this method more universal. It means that the method of assessment of territories' environmental condition based on such criterion may be applicable for evaluation of impact of any environmentally dangerous technogenic object: manufacturing enterprise, solid waste landfill, etc.

4. Discussion of the results of investigation of dangerous technogenic object impact on natural environment.

The carried out investigation of improvement of existing methods of assessment of environmental condition of territories adjoined with environmentally dangerous objects taking into account interrelations between environment components has shown the following.

Significant ecosystem responses characterizing degradation degree in it are the following:

– responses calculated on surface area $\overline{\varepsilon}_S$ (11) and degradation spread speed $\overline{\varepsilon}_v$ (12);

– responses calculated on changes of energy flow indexes in ecosystem trophic structure $\overline{\varepsilon}_P$ (15) and $\overline{\varepsilon}_N$ (16).

This fact is proven by the results of analysis of changes in ecosystem arising under the impact of environmentally dangerous technogenic object. Quantitative values of these ecosystem responses may be determined with statistical data of environmental monitoring, for example, from the environmental passport of the region of any state. Then it is needed to take the average values of statistical data for a long enough period of time (10 years and more) as the allowable limits of indexes. Such approach will support precise evaluation of the depth of degradation processes.

Improvement of the methods of assessment of territories' environmental condition by means of implementation of new environmental reserve criterion allows to carry out operative assessment in short-term perspective on indexes of direct impact $\overline{\varepsilon}_S$ (11) and $\overline{\varepsilon}_P$ (15). Fast evaluation of these responses is possible with application of remote sensing of the Earth surface. At the same time it is possible to assess environmental condition changes in medium- and long-term perspective

of the technogenic object functioning on values of $\overline{\varepsilon}_v$ (12) and $\overline{\varepsilon}_N$ (16). Therefore, environmental reserve criterion formalized with formulas (17), (18), is fully suitable for operative evaluation of environmental dangers and risks of extreme situations occurrence.

Proposed in investigation approach to determination of environmental condition on the value of environmental reserve index $\rho = \{\rho_S, \rho_v, \rho_P, \rho_N\}$ reflects normative approach if the limits of ecosystem responses are equal to those corresponding for catastrophic condition. Then transfer of critical environmental condition into catastrophic one is defined with the statement $\chi^\rho = 0$. The following development of catastrophic ecosystem degradation is characterized with values $\chi^\rho < 0$ (see figure 2).

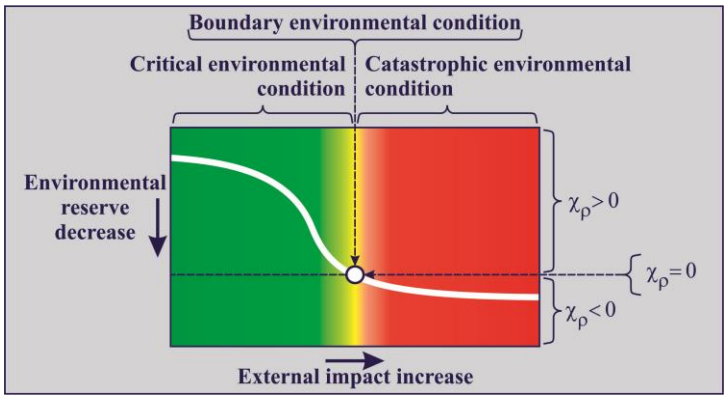

Figure 2 – Determination of the territory' environmental condition with the environmental reserve criterion

The improved method of assessment of environmental condition of territory adjoined to environmentally dangerous technogenic objects using the environmental reserve criterion (18) is unified. This method may be used for operative control of safety of dangerous technogenic objects on level of their negative environmental impact.

For practical realization of method of assessment of the territory' environmental condition systematic investigations are to be carried out. These investigations are to be directed on evaluation of limited allowable values of ecosystem responses for territories adjoined to environmentally dangerous technogenic objects with different negative impact factors.

Conclusions.

1. It is found from the analysis of ecosystem functioning under the environmentally dangerous technogenic object influence that the territory' environmental condition may be fully and uniquely displayed with its ecosystem response on negative impact. This response may be represented with the multitude of energy flow indexes Θ, formalized with equations (3)–(8). Experimental evaluation of the most of these indexes is significantly complicated because of the necessity to carry out the big amount of the field studies over the wide territory. It is needed to narrow the number of significant indexes by means of separating those allowing to assess the territory' environmental condition operatively.

2. The new criterion of environmental reserve of the territory is proposed. It takes into account responses of ecosystem evaluated on:

– surface area $\overline{\varepsilon}_S$ and spread speed $\overline{\varepsilon}_v$ of degradation processes over the territory;

– change of indexes of energy flow in trophic structure of ecosystem. They are deviation of productivity of species of first trophic level $\overline{\varepsilon}_P$ and deviation of population number of species of fourth trophic level $\overline{\varepsilon}_N$ from their equilibrium values.

Developed criterion takes into account both interrelations between elements of natural surrounding and result of impact of environmentally dangerous object on these elements. Implementation of new environmental reserve criterion makes the method of territories' environmental condition assessment applicable for assessment of impact of any environmentally dangerous technogenic object same as for operative environmental safety control.

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ВДОСКОНАЛЕННЯ МЕТОДУ ОЦІНЮВАННЯ ЕКОЛОГІЧНОГО СТАНУ ТЕРИТОРІЙ, ПРИЛЕГЛИХ ДО ЕКОЛОГІЧНО-НЕБЕЗПЕЧНИХ ТЕХНОГЕННИХ ОБ'ЄКТІВ

Оцінювання екологічного стану територій, прилеглих до екологічно-небезпечних техногенних об'єктів, має відбуватися з урахуванням комплексних багатофакторних впливів на довкілля. Проаналізовано процес функціонування екосистеми території під впливом екологічно-небезпечного техногенного об'єкту. В результаті аналізу встановлено, що екологічний стан території можна повно і однозначно характеризувати відгуком її екосистеми на негативний вплив. Значущими відгуками екосистеми території є ті, які характеризують ступінь деградаційних процесів в ній. Узагальнюючими з точки зору оцінювання усього комплексу негативних впливів техногенного об'єкту є два відгуки, які розраховані за площею та швидкістю розповсюдження деградаційних процесів територією. Встановлено також, що відгук екосистеми на негативний вплив може бути виражено у вигляді множини з 36 показників енергетичного потоку через екосистему за рівнями її трофічної структури. Для звуження кількості значущих показників були відокремлені два з них, які дозволяють оперативно оцінювати екологічний стан території. Це продуктивність видів першого трофічного рівня (рослин) та кількість біомаси видів четвертого трофічного рівня (вищих хижаків). Останню запропоновано у спрощеному вигляді виразити кількістю тварин у популяції відповідного виду.

Розроблено новий критерій оцінювання екологічного стану території – критерій екологічного резерву. За вказаним критерієм перетворення кризового екологічного стану території на катастрофічний визначається досягненням показником рівня екологічного резерву нульового значення. Подальший розвиток катастрофічної деградації екосистеми характеризуватиметься значеннями, меншими нуля. Розроблений критерій враховує взаємозв'язки між елементами довкілля й результат впливу екологічно-небезпечного об'єкту на ці елементи. Введення нового критерію екологічного резерву робить метод оцінювання екологічного стану територій застосовуваним для оцінювання впливу будь-якого екологічно-небезпечного техногенного об'єкту та придатним для оперативного управління екологічною безпекою.

Ключові слова: екологічно-небезпечний техногенний об'єкт; екологічний резерв; ступінь деградації; критерій.

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УСОВЕРШЕНСТВОВАНИЕ МЕТОДА ОЦЕНИВАНИЯ ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ ТЕРРИТОРИЙ, ПРИЛЕГАЮЩИХ К ЭКОЛОГИЧЕСКИ-ОПАСНЫМ ТЕХНОГЕННЫМ ОБЪЕКТАМ

Оценивание экологического состояния территорий, прилегающих к экологически опасным техногенным объектам, должно происходить с учетом комплексных многофакторных воздействий на окружающую среду. Проанализирован процесс функционирования экосистемы территории под влиянием экологически опасного техногенного объекта. В результате анализа установлено, что экологическое состояние территории можно полно и однозначно характеризовать откликом ее экосистемы на негативное влияние. Значимыми откликами экосистемы территории есть те, которые характеризуют степень деградационных процессов в ней. Обобщающими с точки зрения оценки всего комплекса негативных воздействий техногенного объекта есть два отклика, которые рассчитаны по площади и скорости распространения деградационных процессов территории. Установлено также, что отклик экосистемы на негативное влияние может быть выражен в виде множества из 36 показателей энергетического потока через экосистему по уровням ее трофической структуры. Для сужения количества значимых показателей были отделены два из них, которые позволяют оперативно оценивать экологическое состояние территории. Это производительность видов первого трофического уровня (растений) и количество биомассы видов четвертого трофического уровня (высших хищников). Последнюю предложено в упрощенном виде выразить количеством животных в популяции соответствующего вида.

Разработан новый критерий оценки экологического состояния территории – критерий экологического резерва. По указанному критерию переход кризисного экологического состояния территории в катастрофическое определяется достижением показателем уровня экологического резерва нулевого значения. Дальнейшее развитие катастрофической деградации экосистемы характеризоваться значениями, меньшими нуля. Разработанный критерий учитывает взаимосвязи между элементами среды и результат воздействия экологически опасного объекта на эти элементы. Введение нового критерия экологического резерва делает метод оценки экологического состояния территорий применяемым для оценки влияния любого экологически опасного техногенного объекта и пригодным для оперативного управления экологической безопасностью.

Ключевые слова: экологически опасный техногенный объект; экологический резерв; степень деградации; критерий.