Methodological Aspects of Complex Ecological Estimation of Man-Caused Territory State and Mathematical Modelling of Processes in a Environment System

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Abstract

The article is dealing with the basics of complex ecological estimation of man-caused pollution state of population aggregate territory of ecological monitoring for solving of ecological problems at macro and micro levels. The appropriate algorithms of the assessment of the health risk and of the ecological standardization problems were developed on basis of analysis of existent approaches of determination of system status and appropriateness of introduction of the risk-analysis for problem solving of state identification.

Key words complex ecological estimation, ecological monitoring, information, entropy function, the risk-analysis.

1. Topicality of the work and its linkage with theoretical and practical tasks

The Ecological estimation (EE) aim is to provide taking into account environment state and ecosystem durability in the development and approval processes of projects, plans for development, programs, and policies. The EE itself is the planning process. It to use prognosis analysis and interpretation of significant affects upon environment, which will be caused by planned activity, and providing information, which is needed during decision-making management.

The EE is used to prevent and minimize unfavourable affect. It also simultaneously estimates real resource potential and maximizes advantages in order to:

– change and improve planned activity project;
– ensure effective resource usage;
– improve social aspects of planned activity;
– determine ways of monitoring and management;
– assist well-grounded decision-making

System of ecological monitoring study the static methods, which do not take time into account as a variable. They include simple and multiple linear and nonlinear correlation and regression, dispersive, discriminate and factor analyses, parameter assessment method. These very methods have been used for analysis of functioning of the local system ecological object, where the soil is the main object of research. Dynamical methods take into account time as a variable and use Fourier analysis, spectral and correlation analysis, weight and transfer functions for model development. In general, such models are regression and other quantitative dependencies, which do not disclose the process mechanism.

Identification of signal structure at the input and output of a system, system response on special conditions, and internal structure of a system are very important for model formation. Such approach allows describing cause-effect relations in ecological or any other system basing on differential equations owing to generated model conception and equations formed, which show the system behaviour. According to R. Shennon (1978), any material system is an assemblage of objects, consolidated by the form (structure) of regulatory interaction or interdependence for its functioning.

There is enough theoretical material in scientific literature, which refers to the problem of creating complex systems for managerial decision making for the purpose of harmonization of interaction in the "nature-society" system. It was suggested to represent the whole world's multiplicity as three hierarchies: natural or biophysical, social and technical. Combination of subsystems of different hierarchies causes to form mixed class systems: ecological-anthropogenic or ecological-economic.

As it is known the harmful factor an effect is determined by the biological response spectrum of the organism to any harmful factor affect. Death, disease, physiological disease symptoms, functional changes of indistinct biological importance, pollutants or their metabolic products accumulation in organs and tissues are possible responses. Three zones are distinguished during harmless pollution levels determination. The first zone (absence of factor affect) is named sub-threshold level. The third zone (toxic influence) is characterized by pathological organism changes caused by the pollutant (disease or its sings). The second zone lies between them. It is the zone of organism changes which are of unclear biological value. Probably such change is connected with protective adjustments. It indicates the environment deviation from the biological optimum.

The best system of ecological management is such a system, which gives preference to the properties of self-maintenance of natural qualities (the principle of careful interference) [1-3]. Such approach takes into consideration harmonization of ecological systems and their internal processes.

It should be mentioned that functioning of both ecological and economic system would be to a considerable degree influenced by the social system, where the state of the human both as a member of society and biological organism is important.

It is necessary to work out a universal approach to solve problems caused by economic activity influence upon environment, by natural and social environment influence upon living organisms and human health.

2. Aims and tasks of the study

The aim of the investigation as to harmonisation of ecological, social, and economic systems development is introduction of the concept of the methodology of complex ecological estimation system (CES) [4, 5] and its usage for determination of ecological state of the territory on the basis of ecological monitoring and implementation of thermodynamic principles when analysing input data.

To achieve this aim the following tasks touched upon in the present work:

1) to determine main approaches to general system state estimation in their present condition their development and external influence;

2) to form methodical approaches to qualitative and quantitative health risk estimation in the sphere of normalization and decision-making concerning secure influence upon human beings.

3. Research materials and scientific results

For ecology, prior to the system analysis, it is usual to examine at first the elementary structural unit, which is the subject of study. The necessary condition of a structural unit construction is that it should maintain all properties of the system. In case of natural ecosystems, biogeocenosis is such a unit. The basis of "society-nature" interaction is social production, whose all abstract issues are included in noobiogeocenosis. The main process, which defines functioning of noobiogeocenosis as the elementary component of the "society-nature" system is the process of work.

System ecological object allows to abstract away from the fine structure of the system and to consider any irregularities in any component as the aberration, which is defined and taken into account in ecological state analysis through thermodynamic parameters. Such approach allows solving the problems of ecological orientation at global macrolevel, as well as at the microlevel for solving local problems (Fig. 1).

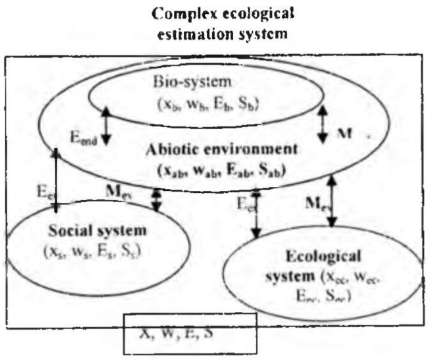

Figure 1. Structure of corporative ecological system

General CES state realization is characterized by the value:

$$S(t) = \int_V S_{dV}^{(p,e,s)}(x_1(t), x_2(t) \ldots x_n(t))dV, \quad (1)$$

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Entropy change is determined as $\Delta S_{dV} \geq 0$ and corresponds to entropy intensity production in object. This takes place in the case of irreversible processes in the system components which are physical chemical systems:

$$\sigma(t) = \frac{dS_{dV}}{dt} \geq 0 \text{ if } t \to 0. \quad (2)$$

This value is connected with new system state

$$P(t)=\frac{dS_{dV}}{dt}=\int_V \sigma(x_1(t),x_2(t)...x_n(t))dV. \quad (3)$$

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$P(t)\to \min$ is a condition to be met for the system to stay within stationary process limits and managerial influence not to cause entropy production.

It is proposed to characterize infringement risk estimation in the macrosystem by integrated index in case of system object. Integrated index takes into account changes inside each subsystem and ecological risk value for each subsystem – ecological (natural), social and economic ones (Fig. 2–3).

The present approach does not take into account related systems state (economic and natural systems) and doesn't let to estimate risk level in these systems and its influence upon population health risk level.

The aim of approaches main to consider to ecological risk estimation formation for territories and the population health the research is state. Corporative concept advantages were determined regarding corporative ecological system and positive risk estimation.

Analyzed indicator groups are distributed among three factor blocks according to the CES concept of corporative approach. Population health belongs to the 1st block; the way of life, social economic environment belong to the 2nd block; biological, chemical, physical and social environment factors belong to the 3rd block (Fig. 2).

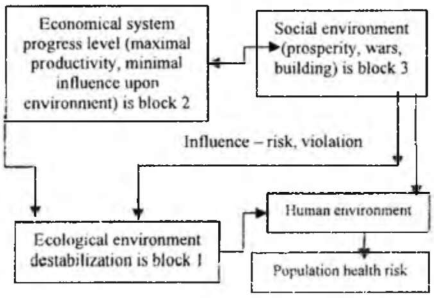

Figure 2 Block schema of population health assessment

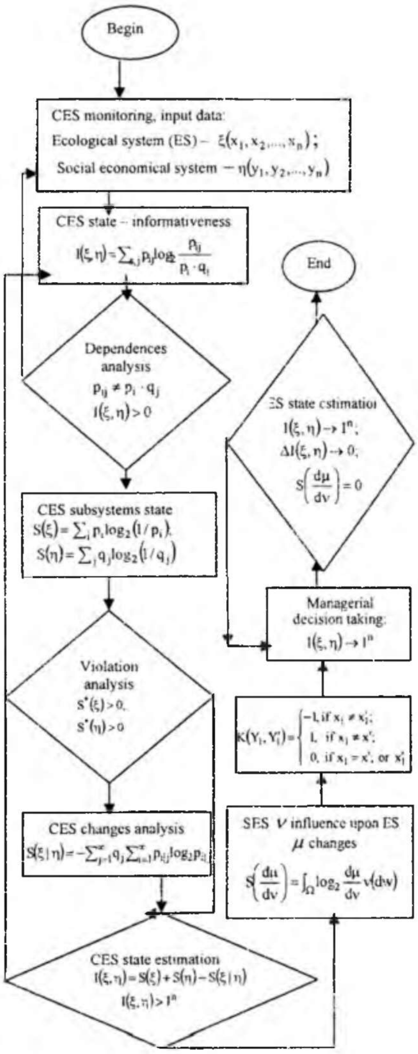

Figure 3. CES state scheme in the form entropy and comparator K*

* - ξ is probabilistic observation $(x_1, x_2, ..., x_n)$ with probability $(p_1, p_2, ..., p_n)$; η is probabilistic observation $(y_1, y_2, ..., y_m)$ with probability $(q_1, q_2, ..., q_m)$; p_{ij} is probability of interaction of operation $\xi = x_i; \eta = y_j$, S is entropy of systems state, μ is

ecological changes to man-made v argument (in accordance with Radona-Nicodima) $(S, w = w(t+\tau)$; I^n is unconfigured state, equilibrium position; *is determination S provided that $I^n = 0$

It is $(S, w = w(t \pm \tau)$; $I^n)$ problems appear to an ecological and economic sense within the framework of complex approach. They concern population health estimation.

1. Research object state, violation probability, destabilizing process risk determination that can be confirmed by entropy value.

2. Forming of standard as estimated values on the influence minimization basis and according to destabilizing factors effect upon living organism (Fig. 4).

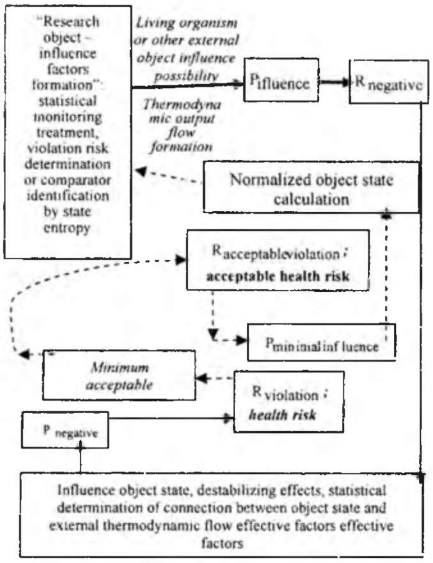

Figure 4. Risk analysis problems with CES realization: → direction and sequence of the 1st problem solving; - - - -► ranking problem decision concerning influence object

This complex approach realization was considered when solving the problem of ecological security violation detection during Dergachivsky refuse dump and water objects monitoring according to the following scheme [4].

Influence risk as informational and influence entropy, if PI doesn't exceeds $x_2 = 1$:

$$Risk = S;\ S(t) = -P(X, x_1, x_2) \cdot \ln[P(X, x_1, x_2)],$$

where $P(X, x_1, x_2)$, $PP(X, x_1, x_2)$ are state, influence possibility:

$$\begin{cases} X = x_i / GDC,\ \sigma(X) = \sqrt{\dfrac{\sum_{i=1}^{length(X)-1} (x_i - \min(X))^2}{length(X) - 1}}, \\ F(X, i) = \dfrac{1}{\sqrt{2\pi}\sigma(X)} \cdot \exp\left[\dfrac{-1}{2(\sigma(X))^2}(x_i - \min(X))^2\right] \end{cases}$$

$$\begin{cases} P(X, x_1, x_2) = \dfrac{1}{\sqrt{2\pi}\sigma(X)} \cdot \left[\begin{array}{l} \dfrac{-1}{2}\operatorname{erf}\left[\dfrac{1}{2}\sqrt{2}\dfrac{(-x_2 + \min(X))}{\sigma(X)}\right]\dfrac{\pi}{2}\sqrt{2}\sigma(X) + \\ + \dfrac{1}{2}\operatorname{erf}\left[\dfrac{1}{2}\sqrt{2}\dfrac{(-x_1 + \min(X))}{\sigma(X)}\right]\dfrac{\pi}{2}\sqrt{2}\sigma(X) \end{array}\right] \end{cases}$$

$$\begin{cases} P(X, x_1, x_2) = \dfrac{1}{\sqrt{2\pi}\sigma(X)} \cdot \left[\begin{array}{l} \dfrac{-1}{2}\operatorname{erf}\left[\dfrac{1}{2}\sqrt{2}\dfrac{(-x_2 + 1)}{\sigma(X)}\right]\dfrac{\pi}{2}\sqrt{2}\sigma(X) + \\ + \dfrac{1}{2}\operatorname{erf}\left[\dfrac{1}{2}\sqrt{2}\dfrac{(-x_1 + 1)}{\sigma(X)}\right]\dfrac{\pi}{2}\sqrt{2}\sigma(X) \end{array}\right] \end{cases} \quad (4)$$

4. Theoretical and Practical Value of Work

The idea of applying of basics of thermodynamics to the area of optimization of managerial decision in the ecological monitoring system is objectively conditioned by the course of investigation – introduction of CES as:

1) essential model of realisation of interaction between complicated dynamical systems: natural, ecological, social and economic;

2) optimisation of managerial decision concerning CES with the aim of harmonisation of natural and social-economic systems relations and their stable balanced development;

3) as the basis of identification and estimation of normalized balanced development of system-system territorial object n of complex approach for solution of micro level ecological problems.

Since CES is directly connected with the system analysis, solution of the tasks assigned is connected with mathematical formulation of compound objects.

5. Summary

The results of analytical research and water state risk analysis calculation application are as follows:

1. CES state determination algorithm (fig. 3) has been devised according to the territorial object and

their components thermodynamic (entropic probabilistic) nature (eq.1-3). Ecological hygienic health risk scheme and chemical factor permissible level have provided according to CES realization and minimal health risk estimation conditions (fig. 4).

2. Complex probability thermodynamic system for source and influence object ecological state estimation has been determined.

Suggested integrated approach realization appropriateness was shown on the basis of example of ecologically dangerous territory state analysis. The analysis aim is to determine ecological danger points and to work out the most constructive managerial decision. The most probable influence factors and thermodynamically conditioned negative influence processes (eq.4, fig. 4) determination is the analysis possibility condition.

6. References

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