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USING THE SYSTEMOLOGICAL BASIS AND INFORMATION ENTROPY FUNCTION IN THE STUDY AT UNCERTAINTY CONDITIONS OF SYSTEM-STRUCTURED OBJECTS

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In the article substantiated the expediency of introducing the basics of systemological analysis in modeling and structuring of studies of complex objects, which allows to establish conditions for the implementation of a certain target function, which is responsible for the state and functionality of the investigated object in certain conditions of the environment, taking into account the macrostate of the complex system, through experiments of microstates, and its changes in the system "object – the environment" regarding the state of external systems using an entropy function according to a consistent analysis of uncertainties and their solution to establish conditions for the stabilization of the object or achieve the goal of regulation situations based on information synergetics. It was concluded that, proposed comprehensive entropy-synergy analysis of the determination of the state "the investigated system – the environment" and changes in the consequence of process transformations in systemic objects in conditions of certain uncertainty does not require additional research, characteristic of known estimates for the criteria in widespread mathematical means decision-making.

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INTRODUCTION

The systemology of complex objects is a means that provides the possibility of solving various scientific, business, managerial and production weakly structured and weakly formalized problems with the help of modern information systems (IS) and information technologies (IT). This is of particular importance in the research of a complex object "system – the environment" view on technogenic and environmental safety. To solve many security issues, it is important not only to establish a state of a complex object, but mostly its functionality in the conditions of presence and variability of the environment. The ecological state of entertainment and any economic activity does not determine the safety, because it is the result of analytics of the information component, which takes into account the qualitative characteristics of the environment in contact with the technosphere, quantitative assessments of their changes in such interaction, the processes of creating direct influence factors on living organisms and a person.

Thus, consideration of security issues in any section of their solution (at the level of macrosystem study, analysis of simple systems) requires complexity in studies, which is ensured by the use of systemological foundations for modeling complex structured systems using the function of information entropy with the inclusion of synergetics and information theory. The introduction of a systematic approach in solving quality and management problems is due, firstly "unsatisfactory ways to describe the behavior of large discrete systems", and secondly, weak structuring and "complexity of real subject areas", interdisciplinary nature of research to achieve a solution of the settlement tasks, obtaining necessary knowledge as a basis for taking weighted decisions.

In a practical section, it is proposed to achieve the goal of finding solutions for problematic security issues in general and ecological in particular in relation to the experimental object in the form of a "system – the environment" due to solving such tasks:

– substantiation of the methodological basis of knowledge-oriented systemological analysis of the complex of monitoring data on the search for target decisions, taking into account the process phenomena of internal and external nature for systems of different nature and complexity due to the use of the entropy approach for modeling conditions and processes;

– testing of the proposed synergistic and entropy analytics of information analysis of objects in relation to the self-organization of their homeostasis processes on the example of the study of self-purification contaminated soils.

1. PROBLEM STATEMENT: MODELING TECHNIQUE

In order to study objects of the type "system – the environment", an algorithmic and software assessment of natural and technogenic objects state is proposed by the results of the probabilized-entropy analysis of monitoring data with the introduction of synergetics provisions.

Methodological basis of a comprehensive study of any object as a systematic formation of the view "object – the environment – (object – the environment) – processes of internal and external nature – (object – the environment) object" it is advisable to build a universal integrated approach covering all stages of system analysis of monitoring data and allows to state the acquisition of knowledge about the object after the end of the cognitive process (Fig. 1).

Trends in the system change to disorganization, which determines the growth of the function of the entropy S state, counteracts information. Increasing the amount of information in the system contributes to increasing its organization, and thus an increase in the certainty of the investigated situation, obtaining knowledge about the object.

The equilibrium functioning of all large systems components in accordance with balanced interaction at the level of subsystems and elements of each of them as a whole is realized thanks to the synergistic effect of the microstan components co-operation in the organizational structure that corresponds to the maximum entropy. The functioning of such systems in the external environment, their condition and properties at time is determined by the energy level:

$$E = E(a_i, b_i, x_i, t), \qquad (1)$$

where a_i, b_i, x_i, t – accordingly, external and internal data parameters indicators, managed parameters and time.

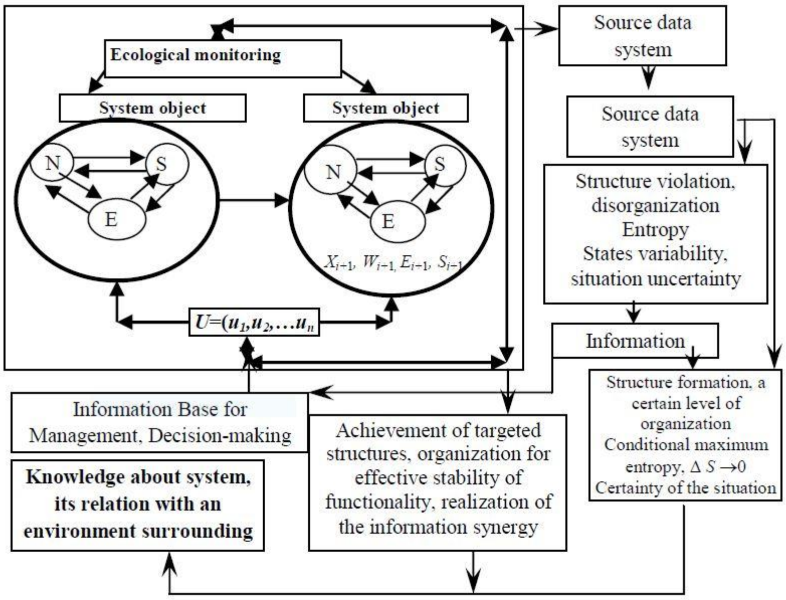

Fig. 1. Scheme of systemological modeling of a system object on an entropy-informational basis with knowledge base: N, S, E – natural, social, economic system; X, W, E, S – composition, structure, energy, entropy; U – management (author's development)

From these positions in environmental research, the facility is provided as a complex of interrelated natural and social systems, technosphere – "Technical shell", artificially transformed space that is under the influence of human activity: X, W, E, S – composition, structure, energy, entropy of biosystems, organism and the environment.

Such organizational and structural interconnection of the components of the system object implements the principle of self-organization in finding a sustainable state due to co-operation, compatible actions of the necessary factors, processes, etc., which is a synergistic effect, causes a synergistic system when combining individual components, supporting the systematic Dynamic state according to the effect of the compatible action of each individual component in the form of their simple sum. It is proposed to study the features of the mutual functioning of socio-ecological and economic systems of equal complexity combination of system analysis elements – entropy, information and synergy [13, 26 - 28].

The close content between entropy and information determines the first as non-abundance of information, and the second as counteraction to entropy, that is, the violation of the established procedure, the need to find new knowledge about new systems and processes. These two measures of complex systems are combined with each other with a negentropy – a characteristic of motion to order, organize the system. Any system interacting with the environment to keep their natural state counteracts surrounding chaos by importing negentropy [25].

The investigated object in this case has a systematic representation in the form of "the object of monitoring (the system – the environment) – data on state and functionality = processes of external influence, internal regulation – processes of self-organization – steady state of the object, stationary (system – environment)". For its comprehensive study, it will be effective in the use of an entropy approach, since for assessing the condition and changes, statics and dynamics, deal with one function, namely entropy.

In the study of processes nature that return a disorganized system from chaos to an orderly structure, elements of synergetics are involved, that is, co-operation of factors interaction of imbalance resolution, unregulated situations. The fixation of the necessary direction of change is traced by the processes of self-organization and the change in the entropy level in the current state of the fixed system due to the sequential use of the elements of the entropy and synergetics in the system analysis of this system object with the inclusion of processes that lead to changes or returning systems to the initial Condition, and thus and the entire object determined as an entropy-information evaluation of the state of system objects (Fig. 2) [29].

According to Fig. 2, systems state is evaluated according to the qualitative-quantitative characteristics of the change in entropy by trajectory of the final structuring of the object in the space of interaction with the surrounding environment. In the conditions of nonlinear development of events and self-existing processes "object – external systems", with a stable structure of the system object of research, it is expedient to use an entropy approach and a phenomenological basis of a consistent solution of situations uncertainty regarding state and processes. In this case, the stochastic and uncertainty of the situation is overcome by the consistent representation and analysis of quality information to obtain results in terms of maintaining appropriate structural stability in the research system “Object – Environment” in accordance with changes in the entropy function ΔS from the analysis of “state – processes”. According to the results, with this approach, it is likely to establish self-propelled regulation of equilibrium in the systemic formation or transition to new equilibrium states with changes that are associated with an increase in entropy in the investigated system (see Fig. 2).

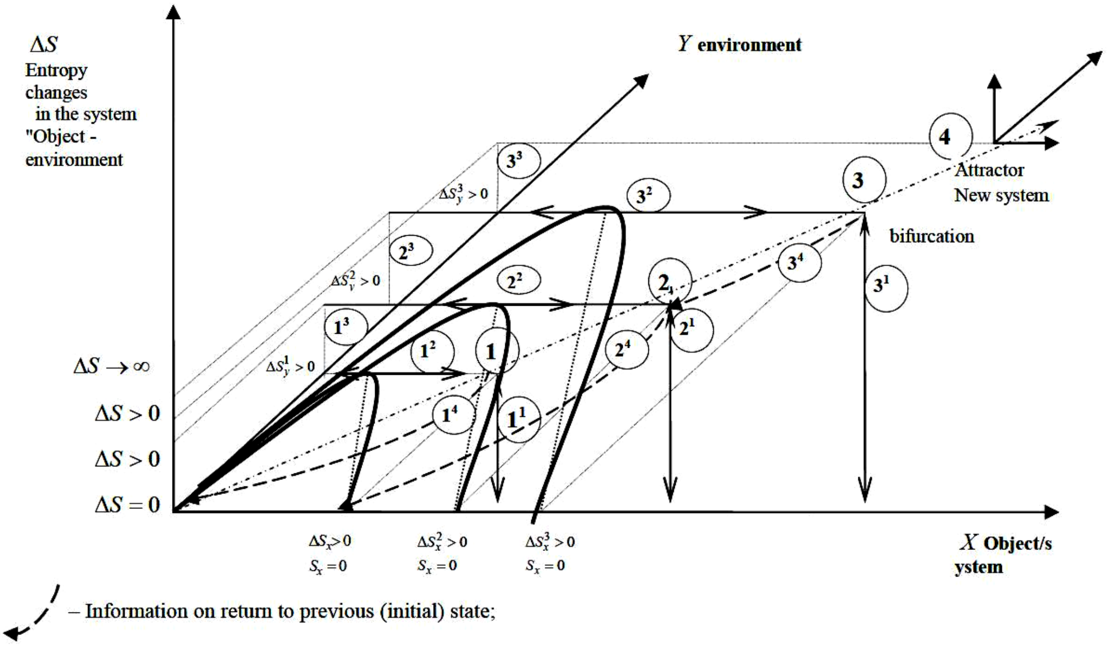

Fig. 2. Scheme for evaluating the state of the study system “object – environment” by entropy approach to the analysis “state – process” (author’s proposal): 1, 2, 3, 4 – system states according to the terms of interaction “object – environment”; 1^1, 2^1, 3^1 – arbitrary reverse processes of returning system to initial state, i.e. $S_x = 0$; 1^2, 2^2, 3^2 – arbitrary processes of mutual influence “object – environment”, which leads to $\Delta S > 0$; 1^3, 2^3, 3^3 – changes in the system “object – environment” on the state of external systems $\Delta S_y^{1,2,3} > 0$, that lead to new states; 1^4, 2^4, 3^4 – self-regulation processes between the object and the environment within the investigated system that maintain equilibrium in the system with its permissible changes $\Delta S_x^{1,2,3} > 0$

The proposed entropy analysis of the analysis is determined by the fact that the object is characterized from the positions of achieving certain goals, observing the permissible normative restrictions, etc. and the implementation of processes in relation to the object of influence of external environment or the possibility of resolving the coexistence situation “object – environment”. In this case, it is necessary to take into account a close relation between entropy and information that is important for interactions with the environment, which is mostly an event of uncertainty.

In time, there is a deviation from stationary in a state of the system, its functional capabilities, the emergence of state stabilizing processes in self-regulation or the course of processes, which is a factor in self-organization, achievement of stationary in a permissible variation. All this sequence is defined as elements of the analytical system *N*, which forms a set *X*, which contains variables *x*. Each element is determined by entropy, which, provided that changes in the system when interacting with the environment (system in the object – the internal environment, with the environment – external environment) is defined as an entropy for the end state with *N* probable consequences (outputs) view p_n (R.V. Hartley, 1928 [33]):

$$S = \log_2 N . \qquad (2)$$

For independent random events *X* with *N* probable states described probabilities $p_n \left(n = \overline{1, N}\right)$, establish medium entropy and associate it with information *I* and the conditions of a particular situation $I = \log_2 N$.

Knowledge Oriented research is expedient to interpret the theory of information that specifies the mathematical apparatus of quantitative determination of information, which is determined by three approaches. The combinator approach provides quantitatively information about the object through its systemic organization, which is consistent with the provision of an object in the form of “system – environment”.

In a combinatorial concept, the amount of information about the object *X* is provided with a given requirement to accuracy, adheres to logical independence from probabilistic assumptions. This approach allows you to determine the amount of information as ε-entropy $S_\varepsilon(K)$. In order to allocate an individual function from the grade of functions for the given conditions of the analyzed system. In the same way, a certain amount of information is used as ε-capacity $C_\varepsilon(K)$ to separate securely disparate elements *K*, the distance from which not less ε [33].

Observation of an object ξ conducted with a given accuracy ε (measurement system, information processing system, etc.) that determines ε-entropy $S_\varepsilon(\xi)$ of an object ξ. By Shannon, this is defined as the speed of creating a message. For ε-entropy, the theorem about the extreme role of normal distribution is maintained: $S_\varepsilon(\xi)$ calculated exactly in case of normal distribution ξ.

Within the analysis of a systematic object, this means that for inpatient and dynamic conditions, its condition is described by a certain function, the change of which indicates an approximation to a certain point of homeostatic relations with the environment, namely the entropy ($S_\varepsilon(K)$) in establishing significant factors of destabilization of the situation in the system "object – environment" and the entropy of the inner homeostasis ($C_\varepsilon(K)$) with regard to the state of the "object system – the internal object environment".

In the case of a systematic submission of the research object, namely the consideration of object system ξ (set X) and system η (set Y), internal interaction between components relative to the requirements of their existence space $X \times Y$ realized on a set of possible pairs U at $a \in X$ and such y with Y_a, that match the condition $(a, y) \in U$. Information entropy in this case is calculated equation

$$\Delta S(y \mid a) = \log_2 N(Y_a), \tag{3}$$

where $N(Y_a)$ – the number of set elements Y_x.

Since the study of complex systemic entities with a system of environment from the object surroundings has a certain degree of uncertainty, it is advisable to information about the state of the system ξ (according to X) to establish relative information about η (according y) thus

$$I(x : y) = \Delta S(y) - \Delta S(y \mid x). \tag{4}$$

In the presence of data for a system object from various monitoring data sources and information consisting of not bound or weakly bound information (indicators, factors, measurement parameters, etc.), subordinated to certain probabilistic laws, is used in the practice of scientific research is probabilistic approach. Within its limits are allowed with significant over time and volume of observation of probabilities and frequencies mixing; formation of mathematical expectation for entropy $MS_W(y \mid x)$ and information $MI_W(x : y)$, the value of which can take excellent value (with a combinator approach, it is always a positive value that is taken into account for an idea of information amount).

According to A.N. Colmogorov [33], the true measure of the amount of information is the averaged value $I_W(x, y)$, characterizing the density of communication between systems ξ and η, state parameters *x, y* symmetrical way: $S_W(x \mid x) = 0$, $I_W(x : x) = S_W(x)$, $I_W(x, y) = MI_W(x : y) = MI_W(y : x)$ with the fact that $S_W(y \mid x)$ and $I_W(x : y)$ are functions from *x*.

The amount of information to set an accurate value ξ In the presence of a well-known and sufficient volume of values $\eta = y_j$ is equal

$$S(\xi \mid \eta = y_j) = -\sum_i p_{i|j} \log_2 p_{i|j},$$

where $P\{\xi \equiv x_i\} \equiv p_i$ – probability of characteristics in relation to parameters values of the systems i-th state ξ; $P\{\xi = x_i, \eta = y_j\} = p_{ij}$ – additional distribution for a random object η with consideration of the compatible probability distribution (in the proposed version of the analysis according to Fig. 2 $\Delta S(\xi \mid \eta = y_j) = -\sum_i p_{i|j} \log_2 p_{i|j}$, where $p_{i|j}$ is the difference between the probability of obtaining data / information on the investigated object and the actual existing state of it with clearly defined properties or target, that is

$$p_{i|j} = \Delta p_{i|j}, \tag{5}$$

that averaged

$$MS(\xi \mid \eta) = -\sum_j P(\eta = y_j) \sum_i p_{i|j} \log_2 p_{i|j},$$

and on the suggestion

$$M\Delta S(\xi \mid \eta) = -\sum_j P(\eta = y_j) \sum_i p_{i|j} \log_2 p_{i|j},\ p_{i|j} = \Delta p_{i|j}, \tag{6}$$

where $S(\xi \mid \eta)$, $\Delta S(\xi \mid \eta)$ – conditional entropy and change of conditional entropy η at $\xi = x$; $MS(\xi \mid \eta)$ and $M\Delta S(\xi \mid \eta)$ – mathematical expectation of conditional entropy and change of conditional entropy in variable characteristics ξ or system state ξ [24, 28].

The amount of information relative ξ, contained in the results obtained (task) or determined appropriately due to characteristics for the system η, equal to the difference

$$I(\xi \mid \eta) = S(\xi) - MS(\xi \mid \eta);$$

and information changes to the investigated object will be $\Delta I(\xi \mid \eta) = \Delta S(\xi) - M\Delta S(\xi \mid \eta)$ according to the observation data received

$$I(\eta|\xi) = -\sum_i p_{ij} \log_2 \frac{p_{ij}}{P\{\xi = x_i\} P\{\eta = y_j\}}, \tag{7}$$

$$\Delta I(\eta|\xi) = f(\Delta p_{ij}).$$

According to equations (2) - (5) we have the final calculation definitions of changes for the state of the investigated object in the field of its existence W, in particular the information $\Delta I_W(x : y)$:

$$\Delta S_W(x) = -\sum_x \Delta p(x) \cdot \log_2 \Delta p(x);$$

$$\Delta S_W(y \mid x) = -\sum_i \Delta p(y \mid x) \cdot \log_2 \Delta p(y \mid x);$$

$$\Delta I_W(x : y) = \Delta S_W(y) - \Delta S_W(y \mid x). \tag{8}$$

In the study "object – environment" system, it is advisable to have information on changing the probability to maintain a macro-source that is responsible for targeting equilibrium in space and processes in such a system according to the statistical function of the Boltzmann entropy (see Fig. 2):

$$\Delta S = k \cdot \ln \Delta \Omega , \tag{9}$$

where k – the coefficient of proportionality, constant Boltzmann; k = 1.38 10^{-23} J/K; $\Delta \Omega$ – changes in the number of possible microstates (methods), which can be compiled by this macroscopic state of the system that identifies the number of system microstates, provided that all microstates are equal.

Provided changes in the system when the object interacts with the environment receive certain N-probable consequences (outputs) p_n, of which interesting is changed ΔN, that determine the realization of equilibrium or intended purpose in accordance with changes in Hartley entropy:

$$\Delta S = \log_2 \Delta N . \tag{10}$$

Such a sequence of obtaining a chain of entropy changes in the analysis of states and processes allows you to move in the direction of probable trajectories in the space “object – environment”, which leads to a goal or desired development in such a system or facility in existing conditions. The level of knowledge about the system state (finally accepted solution) is defined as Shannon's information entropy for independent changes in events X, which corresponds to ΔN-altered probable states described by probabilities $p_n \left(n = \overline{1, N} \right)$:

$$\Delta S_x = -\sum_{n=1}^{N} p_n \cdot \log_2 p_n = -M \left[\log_2 \Delta p_n \right]. \tag{11}$$

The final finding result is rated in this way:

- minimum probability of change corresponding to the implementation of the necessary macro state, unit probability;

- maximum probability of change corresponding to uniform probability distribution ofstates realization that are closed to solution according to $\Delta n = \overline{1, \Delta N}, \Delta p_n = 1 / \Delta N$;

- zero value for other cases when changing statistical entropy by Shannon:

$$\Delta S_x = -\sum_{s=1}^{l} \frac{\Delta N_i}{\Delta N} \cdot \ln \frac{\Delta N_i}{\Delta N} , \tag{12}$$

where ΔN_i – changes in the number of elements in the i-th species in the total number of changes in the investigated system ΔN.

The final state is established by a structural entropy, according to which the desire of the system to equilibrium is formed ($\Delta S \to 0, S_1 \to \min \to \Delta S > 0, S_2 \to \max$) [24, 27, 32].

In all decisions, the system or object must reach the attractor – structure (function), which specifies (determines) stable system state (synergetics, nonlinear thinking). Thus, a probable state of the system is realized, a probable purposeful action is likely to lead to the maximum ordering and self-organization of the object, achieving the synergy of the information flow.

2. REVIEW OF THE LITERATURE REGARDING THE METHODS OF STUDYING COMPLEX OBJECTS SUCH AS “SYSTEM – ENVIRONMENT”

In general, in the performance of a comprehensive analysis of a complex research object, it is in mind that any system with its functional properties is a consequence of the functional request of the subsystem to its specific function. Under this position in scientific research, it is advisable to draw attention to the search for decisions in accordance with the provisions and principles of systemology, which considers the object, taking into account the level of its systematic.

The essence of systemologies as a methodology of system analysis and the theory of complex systems, which is an expanded principle of integration, unity and communication, concentration, modeling, productivity, uncertainty, decentralization, which applies to systemic research and determines the essence of the system organization of the object [1 - 3]. The system is considered as a dynamic object, along with the process of its emergence, formation and functioning when interacting with surrounding external systems [1, 2].

Given the features of ecology tasks solution, which deals with complex objects, with the lack of objective models for obtaining a generalized assessment of alternatives quality, if necessary, taking into account the set of criteria (environmental, economic, technological, etc.), when choosing an optimal decisions it is relied on a decision maker (DM). To increase the DM objectivity, it is necessary to provide an area of research as objective information. Information about objects of problem area (PA) and their properties are proposed in the knowledge base (KB) of the intellectual system of expert analysis of the environment state, forecasting and prevention (IseaFP) of emergencies. Thus, for a weakly structured problem of choosing an optimal environmental measure to prevent the possibility of a emergencies on objects of industrial production, the provisions of the systemological cognitive approach [4] are implemented.

Taking into account the above and the needs of environmental research in ecological methods, in the paper, a proposal for consideration of the research object in the form of a systemic formation “System – environment” is supplemented by the system of processes that ensure the interaction of these components as integrity, providing equilibrium and stability.

The specific manifestation of the systemic principle of systemicity in a complex system organization of the experimental object is a phenomenon or synergy law. The basis of the analytical research system of such an object is the theory of self-organization, which is a science of complicated and steady unequal, non-stationary and structures associated with synergetics as a theory of self-organization, dissipative structures, dynamic chaos [7 - 9].

The research object in case of the use of such an interdisciplinary on the essence of the approach is the system of the real environment of socio-ecological and economic purposes, which are for the target problem – a scientific understanding of complexity and rational explanation of the relationship between the complexity with the laws of nature [10 - 20].

In these works, the synergistic approach is prospective for scientific research of open systems in various areas of knowledge about the state, functional abilities and development of natural, humanitarian systems and objects of technosphere. In general, in most cases, under synergetics understand (from gr. Synerge-Tikos – a common, coherent, active) scientific direction, which studies the links between elements of the structures that are formed in open systems due to intensive (streaming) metabolism and energy from the environment by non-equilibrium conditions. In such systems, the behavior of subsystems is determined by coherence, which is associated with the phenomenon of self-organization when the degree of their ordering with a decrease in entropy is increased. In the study of environmental systems and the use of natural resources, an index based on entropy is proposed to establish an optimal species, for example, a hydraulic system and its water mitigation, an entropy assessment on the tasks of avoiding natural and man-made hazards [21 - 23].

Within the complex scientific research of a systematic object as a "system – environment" principles of systemological analysis inhibit (dynamics) systems and in accordance with the provisions of synergetics as the theory of achieving a system of target destination (equilibrium), and as a consequence of the acquisition of scientific Knowledge about the research object in the conditions of this environment. In the proposed natural-man-made objects of the study as systemic formations used entropy, which is an evolutionary function of the state within the field of synergetics, that is, the basis of system self-organization from chaos in accordance with the directions of its target implementation [23 - 28]. The paper proposes to use the entropy approach of scientific search from the position of the universality of entropy function as a characteristic of the state of the object as a whole, the state of components and processes that provide equilibrium coexistence of systems within the object (internal homeostasis) and with systems of environment (external homeostasis).

3. MATERIALS AND METHODS

According to the proposed systemological information and entropy approach based on the theory of system analysis and synergetics of a complex study of a complex object in the sequence of "system state – excitation – the process – stabilized system state", experiments on the possibilities of soil abilities realization to self-cleaning due to the growth of heterogeneity of the factor are conducted. External influence on this natural system, including man-made sources (the basis for analysis, served as many years of study by the author about the features of the behavior of anthropogenic loaded soils by their state on the territory of the Zmiyivan landfill and in Kharkiv (Ukraine) 1995-2009 [32]).

The paper proposes a systemological model of a complex object of the species "soil − external environment − influence factors − processes (results of change) perception of external actions − synergy space − equilibrium (soil − environment)" (Fig. 3).

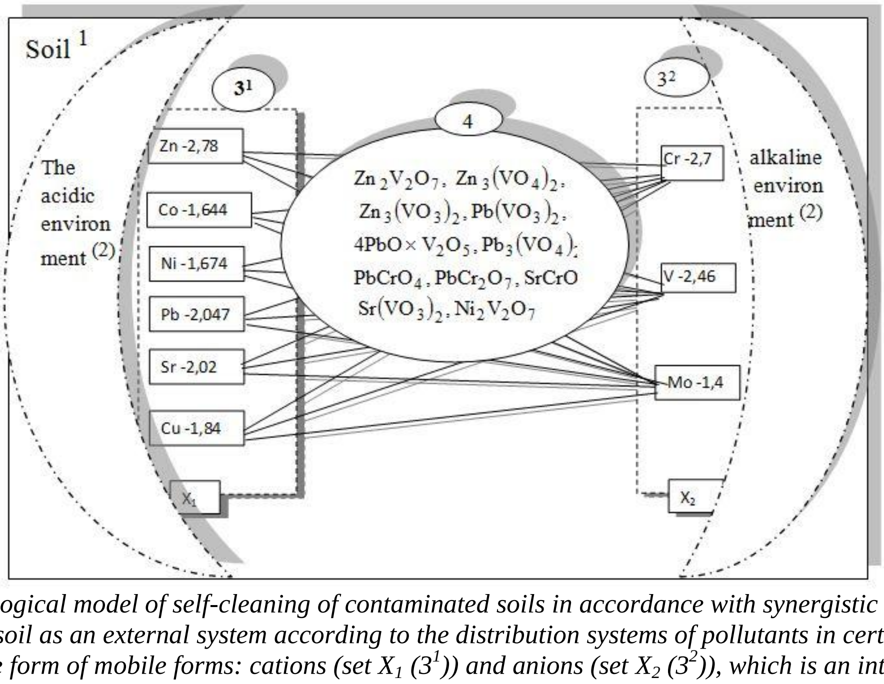

Fig. 3. Systemological model of self-cleaning of contaminated soils in accordance with synergistic and entropy analysis: 1 – soil as an external system according to the distribution systems of pollutants in certain layers of soils (2) in the form of mobile forms: cations (set X_1 (3^1)) and anions (set X_2 (3^2)), which is an internal system of research (pollution zone where the condition of pollutants is determined through the entropy value of violations of maximum permissible values); 4 – the effective system of chemical transformations as information synergy, which is the process of self-cleaning

To describe the transformation in the migration stream of heavy metals (HM), which are soil pollutants, used entropy analysis of arbitrary processes of formation of insoluble compounds, and as a result of the accumulation of HM in the soil and the absence of them in the biomaterial. Self-cleaning of the soil, thus, is determined by the probability of binding of pollinants into insoluble compounds (system 4 − processes (changes in changes) perception of external actions 4 in Fig. 3).

Violation of the discrepancy between the state of environmental safety of soils at the accepted level of changes in the HM content in them is an internal system of research, characterized by certain entropy load – the entropy value of discrepancies with the established safety standards (formulas (8-12)). This system is a geochemical subspace of the soil system $A_1, A_2, \ldots, A_m$ (m – dimension), for which $(x_1, x_2, \ldots, x_m)$ components make up factors of influence in the form of $x_1 \in A_1, x_2 \in A_2$, that is the subject space from cationic and anionic forms of HM $A_1 = A_2 = \ldots = A_m = U$:

$$U = \left\{ \underbrace{\mathrm{Zn, Co, Ni, Pb, Sr, Cu}}_{x_1}, \underbrace{\mathrm{Mo, Cr, V}}_{x_2} \right\}.$$

To assess the safety of HM receipt in environmental objects in accordance with the soil, a characteristic is given in the form of relations: $\{x_1, x_2\}$ $m = 2$, $A_1 = \{\mathrm{Zn, Co, Ni, Pb, Sr, Cu}\}$, $A_2 = \{\mathrm{Mo, Cr, V}\}$, then $S = A_1 \times A_2$ there is a pairs set of view (x_1, x_2), for which ratio are formed by the value of the entropy state, that is, the analysis of changes in changes and self-organization capabilities of the soil system as a whole. Relationships that are parts of the same space, single-type, implemented operations: association – disjunction $\vee \cup$ "or"; section – conjunction $\wedge \cap$ "and". To analyze the state of heavy metals in the soil adopted for environmental safety values, the probability of deviationing their number in the soil from the normatively established limitation of small risk – 20%, which is a system for evaluating ecological well-being in the form of

$$P(x_1 - x_n) = \begin{cases} 1, \text{ if } x \le 0.2; \\ 0, \text{ if } x > 0.2. \end{cases} \qquad (13)$$

4. EXPERIMENTS. RESULTS

In order to identify the unauthorized processes of binding heavy metals in the soil take into account that the entropy assessment of the established bonds between the defined forms of HM in the soil should increase in negative values. In accordance with this, an assessment of soil condition is provided – polluting elements are in a bound state, which reduces their migration capabilities in the adjacent medium (Table 1).

Table 1

Comparator Identification of heavy metals under the entropy of the violations of safety requirements

Element	Entropy state	Comparator	Cr	V
Zn	-2.265	1	1	1
Co	-1.619	0	1	1
Ni	-1.616	0	1	1
Pb	-2.042	1	1	1
Sr	-1.687	0	1	1
Cu	-1.844	0	1	1
Mo	-1.462	0	1	1
Cr	-2.639	1	1	1
V	-2.434	1	1	1

Reflection "Excess" of the natural level of HM content due to the technogenic "receipt", "interaction" in the soil with its components (sorption) and among themselves in a migration flow, taking into account the combination of these processes for each element (conjunction $P' \cap Q$) determine based on safety assessment in the form $P' = x^0y^0 \vee x^0y^1 \vee x^0y^2 \vee x^0y^3 \vee x^0y^4$ (where x^0, y^0– Zn, y^1 – Ni, y^2 –Pb, y^3 – Sr, y^4 – Cu) According to the formed base of their identified state (Table 2).

Table 2

Comparator identification of elements state by the results of combining processes

	Zn	Ni	Pb	Sr	Cu
Zn	1	1	1	1	1
Ni	0	0	0	0	0
Pb	1	1	1	1	1
Sr	1	1	1	1	1
Cu	0	0	0	0	0

According to the resulting perfect disjunctive normal form (PDNF) form $P' = x^0y^0 \vee x^0y^1 \vee x^0y^2 \vee x^0y^3 \vee x^0y^4$ (where x^0, y^0– Zn, y^1 – Pb, y^2 –Sr, y^3 – Cr, y^4 – V) provide data of HM state in the soil (Table 3).

Table 3

Assessment results of heavy metals in the soil

	Zn	Pb	Sr	Cr	V
Zn	0	0	0	1	1
Pb	0	0	0	1	1
Sr	0	0	0	1	1
Cr	1	1	1	0	0
V	1	1	1	0	0

Taking into account the section of Zn states in accordance with the state of other heavy metals present is determined, PCNF of the form

$$x^0y^3 \wedge x^0y^4 \wedge x^1y^3 \wedge x^1y^4 \wedge x^2y^3 \wedge x^2y^4 \wedge$$
$$\wedge x^3y^0 \wedge x^3y^1 \wedge x^3y^2 \wedge x^4y^0 \wedge x^4y^1 \wedge x^4y^2.$$

The random processes of HM accumulation are recorded, with a small P deviation from the minimum content; The stability of the provision of a "positive state" is determined by a significant deviation from the permissible limitation of the presence of an element in the soil and the course of the compounds-forming processes: $x^i \le -2.3$, if $P = 0.1$ and $y^j \le -2.99$, if $\alpha = 0.05$, $P = 0.95$. Taking into account the data in Table 1 and the above expression, PCNF has such an assessment of elements state by comparative identification [14]:

Zn	x^0=–2.78	$1 \cdot 1 \wedge 1 \cdot 1$	**1**
Pb	x^1=–2.04	$0 \cdot 1 \wedge 0 \cdot 1$	**0**
Sr	x^2=–2.02	$0 \cdot 1 \wedge 0 \cdot 1$	**0**
Cr	x^3=–2.7	$1 \cdot 1 \wedge 1 \cdot 1 \wedge 1 \cdot 1$	**1**
V	x^4=–2.46	$1 \cdot 1 \wedge 1 \cdot 1 \wedge 1 \cdot 1$	**1**

Thus, phenomenological knowledge about the HM behavior in environment objects, taking into account arbitrary processes by entropy-synergistic analysis of the situation, allow to substantiate their state and confirm the results of comparator identification, taking into account "state – process" due to the use of PDNF and DCNF and experimental measurements [32]. This allows you to establish a risk factor, the probability of leveling its negative influence due to the processes of transformation of the urgent flows in the presence of other negative components.

In order to implement in practice, the safety control of natural-man-made territorial formations on the method provided by the method of assessing the quality of complex systems was formed. To implement these tasks in practice, such a sequence of automated information processing (Fig. 4) [34] is proposed.

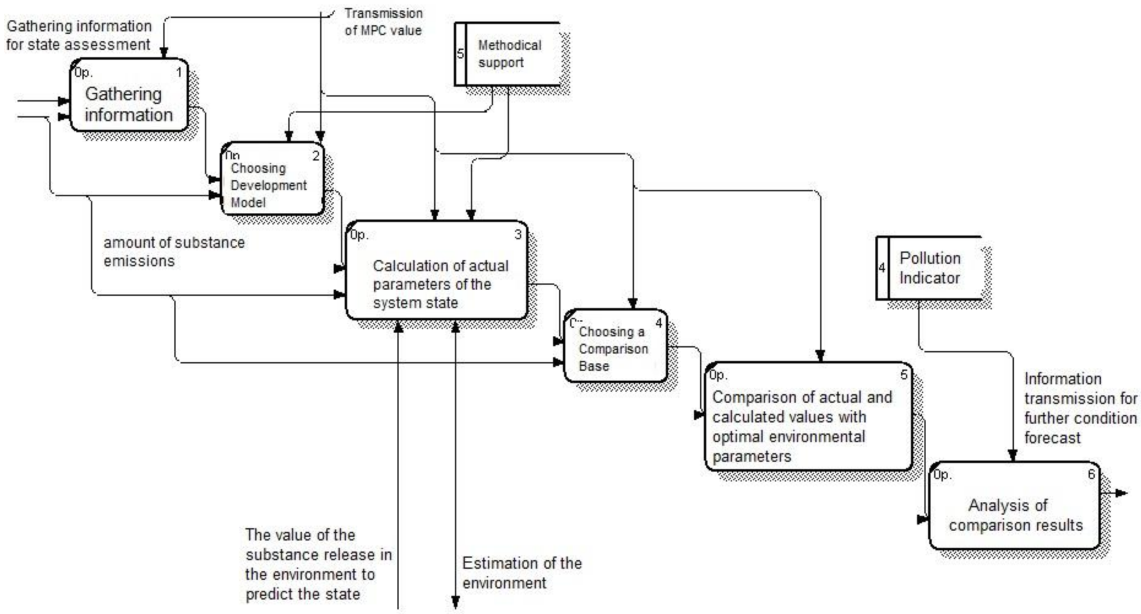

Fig. 4. Data stream chart

Developed a program application in the language Python. As a result of the software application, the structure of knowledge-oriented base (Fig. 5) is determined.

```
article2
logarifm: -1.6191095219925098
logarifm: -1.6157766896652785
logarifm: -2.0417814419604015
logarifm: -1.6865978904862173
logarifm: -1.8442438836515007
logarifm: -1.4617134088173445
logarifm: -2.6388443485319475
logarifm: -2.4337695892371842
Thus, harmful substances on the investigated area are:
Zn - 1;Pb - 1;Cr - 1;V - 1;
Process finished with exit code 0
```

Fig. 5. Python program realisation

Thus, the proposed comprehensive entropy-synergy analysis of the determination of the state "the investigated system – the environment" and changes in the consequence of process transformations in systemic objects in conditions of certain uncertainty does not require additional research, characteristic of known estimates for the criteria in widespread mathematical means decision-making; Data processing results are invariant with respect to the data processing method, in accordance with reality, while using known means of criterion evaluation of environmental protection level, the result depends on the analytical method and subjective experiences of the researcher.

CONCLUSIONS

1. In the article substantiated the expediency of introducing the basics of systemological analysis in modeling and structuring of studies of complex objects, which allows to establish conditions for the implementation of a certain target function, which is responsible for the state and functionality of the investigated object in certain conditions of the environment, taking into account the macrostate of the complex system, through experiments of microstates, and its changes in the system "object – the environment" regarding the state of external systems $\Delta S_y^{1,2,3}$ (see Fig. 2) using an entropy function according to a consistent analysis of uncertainties and their solution to establish conditions for the stabilization of the object or achieve the goal of regulation situations based on information synergetics.

2. An example of a solution of problematic issues to stabilize the state of impaired soil pollution under certain conditions for probabilistic entropy, obtaining information on the safety probability of this situation in the implementation of synergistic effects of self-cleaning, and thus solving the issues of environmental friendliness of the functioning of natural-territorial objects socioeconomic purpose (see Figs. 3-6).

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ВИКОРИСТАННЯ СИСТЕМНО-ЛОГІЧНОЇ ОСНОВИ ТА ФУНКЦІЇ ІНФОРМАЦІЙНОЇ ЕНТРОПІЇ ПРИ ДОСЛІДЖЕННІ В УМОВАХ НЕВИЗНАЧЕНОСТІ СИСТЕМНО-СТРУКТУРОВАНИХ ОБ'ЄКТІВ

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Розглянуто доцільність впровадження основ системного аналізу в моделюванні та структуруванні досліджень складних об'єктів, що дозволяє встановлювати умови для здійснення певної цільової функції, яка відповідає за стан та функціональність досліджуваного об'єкта в певних умовах навколишнього середовища, з урахуванням макростану складної системи, через експерименти мікростанів, та його зміни в системі «об'єкт – навколишнє середовище» щодо стану зовнішніх систем за допомогою функції ентропії відповідно до послідовного аналізу невизначеності і їх вирішення встановленням умов для стабілізації об'єкта або досягнення мети ситуацій регулювання на основі інформаційної синергетики. Було зроблено висновок, що запропонований комплексний аналіз ентропійно-синергетиного визначення стану «досліджувана системи – навколишнє середовище» та зміни внаслідок процесів трансформацій у системних об'єктах в умовах певної невизначеності не вимагає додаткових досліджень, характеристик для відомих оцінок для критеріїв у поширених математичних засобах прийняття рішень.

ИСПОЛЬЗОВАНИЕ СИСТЕМНО-ЛОГИЧЕСКОЙ ОСНОВЫ И ФУНКЦИИ ИНФОРМАЦИОННОЙ ЭНТРОПИИ ПРИ ИССЛЕДОВАНИИ В УСЛОВИЯХ НЕОПРЕДЕЛЕННОСТИ СИСТЕМНО-СТРУКТУРИРОВАННЫХ ОБЪЕКТОВ

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Рассмотрена целесообразность внедрения основ системного анализа в моделировании и структурировании исследований сложных объектов, что позволяет устанавливать условия для осуществления определенной целевой функции, которая отвечает за состояние и функциональность исследуемого объекта в определенных условиях окружающей среды, с учетом макросостояния сложной системы, через эксперименты микросостояний, и его изменения в системе «объект – окружающая середа» по состоянию внешних систем с помощью функции энтропии в соответствии с последовательным анализом неопределенности и их решения определения условий для стабилизации объекта или достижения цели ситуаций регулирования на основе информационной синергетики. Был сделан вывод, что предложенный комплексный анализ энтропийно-синергетического определения состояния «исследуемая система – окружающая среда» и изменения вследствии процессов трансформаций в системных объектах в условиях некоторой неопределенности не требует дополнительных исследований, характерных для известной оценки критериев в распространенных математических методов принятия решений.