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INTEGRATED INFORMATION SYSTEM ASSESSMENT OF COMPLEX OBJECTS SAFETY LEVEL

Надано теоретично-практичні основи інформаційно-системного підходу з комплексної оцінки якості складних об'єктів. Розроблено інформаційно-програмне забезпечення обробки даних досліджень з застосуванням теорії системного аналізу і сучасних засобів надання знань. Працездатність сформованого інформаційно-методичного забезпечення для комплексного дослідження складних об'єктів на ентропійно-інформаційній основі показана на прикладі оцінки відповідності стану і розвитку конкретних природно-техногенних, еколого-економічних систем, проведенні оперативного контролю якості та безпеки технологічних процесів.

Ключові слова: екологічна безпека, методи системного аналізу, математичні методи моделювання, інформаційна система моніторингу, ідентифікація стану безпеки, екологічні знання-орієнтовані системи, інформаційно-програмне забезпечення оцінки якості систем.

Предоставлено теоретико-практические основы информационно-системного подхода комплексной оценки качества сложных объектов. Разработано информационно-програмное обеспечение обработки данных исследования с использованием теории системного анализа и современных способов предоставления знаний. Работоспособность сформированного информационно-методического обеспечения для комплексного исследования сложных объектов на энтропийно-информационной основе показана на примере оценки соответствия состояния и развития конкретных природно-техногенных, эколого-экономических систем, проведении оперативного контроля качества и безопасности технологических процессов.

Ключевые слова: экологическая безопасность, методы системного анализа математические методы моделирования, информационная система мониторинга, идентификация состояния безопасности, экологические знание-ориентированные системы, информационно-програмное обеспечение оценки качества систем.

The complex methodological approaches for solving problem tasks objects quality assessment are determined on the basis of system analysis means combination and of the information and software complex development of research data processing with use of modern mean knowledge providing. Methodological support is based on theoretical knowledge in field of information entropy theory, synergetic, knowledge-oriented databases development; information space of integrating entities unity principles. The scientific and practical foundations of methodological and informational support for the determination of complex systems state assessment and their functional capabilities, safety level of the investigated objects, using of knowledge-oriented information systems for obtaining knowledge on the research objects results at level "state (system – environment) – change – process – system state". The generalized algorithmic approach from complex system object analysis as integrity having its microstructure to which it is proposed to attribute not only component components and elements, but also processes of its functioning is developed. Practical implementation of the proposed informational and methodological approaches for complex systems study analysis on the entropy-information basis is shown on the results of quality and safety functioning assessment of natural-technological, ecological-economic systems, providing operational control and safety management of technological processes.

Keywords: environmental safety, methods of system analysis, mathematic modeling methods, information monitoring systems, safety state identification, environmental knowledge-oriented systems, information program of systems quality assessment.

Introduction. Modern system theory presupposes the existence of systemic entities in the form of socio-economic, socio-ecological, ecological and economic objects of natural and man-made content, which relate to complex systems, and, in accordance with sustainable development provisions, they are united in socio-ecological and economic research objects [1, 2]. A special component for such systems is an information component that takes into account the qualitative characteristics of both individual elements and their relationships. The unstable systems state leads to crises that are conventionally equated with qualitative transformations in them. Thus, the study of modern complex systems is becoming relevant in the processing of information data in accordance with the standard system approach and the latest methods of information theory.

Decision-making is an analogue of information exchange and is the basis of activity, including management. The decision is determined by the achievement of the goal in choosing the best (more acceptable, optimal) alternative from possible variety of options for the purpose.

Under the research object study or development in accordance with the general definition of J. Clare [1] is understood part of the world, which for a given period of time is a unit that reflects the natural (ecological), economic and social aspects of life. The object interacts

with environment, which is central to the investigated integrity (as opposed to existing approaches in solving complex system problems, because it is the basis of the functionality of the object).

The study goal and tasks. The works goal consist comprehensive methodological approaches in solving problem environmental safety tasks of complex objects quality assurance based on the information and software data research development using the system analysis theory and modern knowledge provision. According to the goal is necessary:

1) grounded evaluation methods system compliance to state, features natural and industrial systems environmental quality requirements in economic conditions maintaining the necessary environment environmental safety level, sustainable system objects stability development under uncertainty and risk by reaching environmental safety state;

2) identified information and methodological support composition of complex objects comprehensive study constituted system analysis methodology provision;

3) realized practical application of systematic methodological support for the complex study of complex objects on the basis of a sequential analysis.

At research tasks setting and justifying, allocating domains, checking the models adequacy used knowledge of general systems theory, mathematical logic, including

comparator identification method, information theory and synergy. For creating the researched system object model and tool justification in solving complex systems quality assessment problems applied theoretical knowledge in environmental safety, synergy, information analysis, knowledge-oriented databases development, unity information integrable entities space principles fields.

Scientific results. According to research tasks defines the main ways models and methodological approaches improving complex systems safety level evaluation by analyses “state (system – environment) – changes – process – system state”. Defined methods characteristics state investigation “system – environment” according to the methodological approaches analysis in the environmental, ecological and economic analysis fields to environmental safety assess. The methods system information data disparate objects monitoring comprehensive assessment, entropy and knowledge base processing methods, analysis and environmental and socio-economic information evaluation is offered.

To assess ecological safety level “system – environment” proposes an algorithm (fig. 1) for

probabilistic-entropy approach implementation to determine the state by information amount ξ , which is contained in obtained previous stage results of the problem solution or is established relatively to the system characteristics η . The research object general condition is determined by such dependencies of the information function [3–5]

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

$$I(\eta|\xi) = -\sum_i p_{ij} \log_2 \frac{p_{ij}}{P\{\xi = x_i\}P\{\eta = y_j\}}, \quad (1)$$

where $I(\xi|\eta)$ – amount of information in ξ relatively η ;

$I(\eta|\xi)$ – amount of information in η relatively ξ ;

$S(\xi)$ – state entropy ξ ;

$MS(\xi|\eta)$ – conditional entropy expected value at variable ξ ;

p_{ij} – compatible probability distribution.

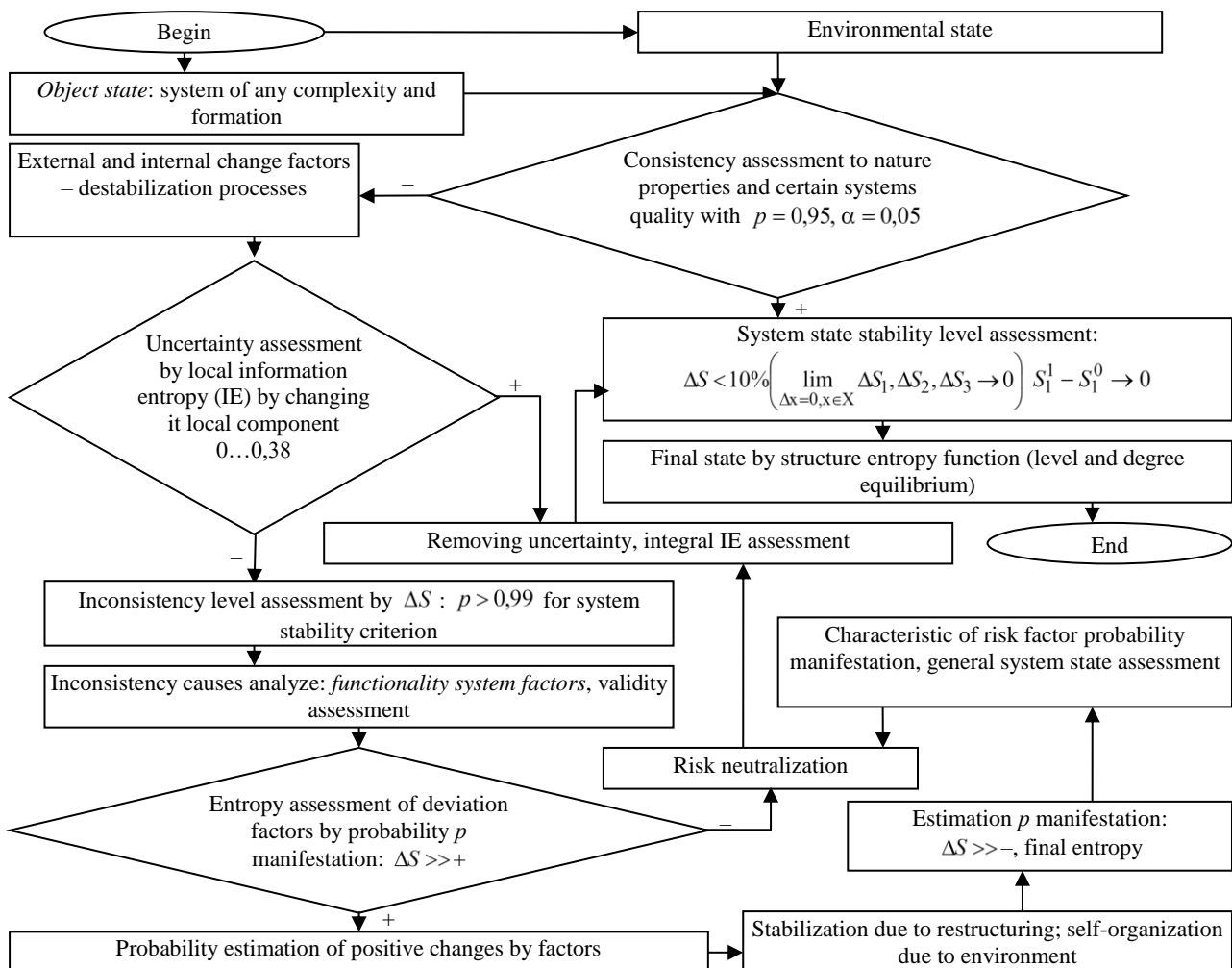


Figure 1 – Probabilistic-entropy assessment of system state and risk factors:

p – probability of matching the natural properties; α – estimation error; ΔS , ΔS_1 , ΔS_2 , ΔS_3 – estimation of general changes, probabilistic, stochastic, random processes respectively

As ξ and η determine the same ratio: the amount of information in η relatively ξ and amount of information in ξ relatively η , then $I(\eta|\xi) = S(\xi)$.

Found that organizational and technical systems related to fuzzy conditions system of their operation, requiring appropriate phenomenological framework usage of experience, knowledge, based on knowledge-based information systems. Applied only thermodynamic nature as a basis for object systems modeling, which permitted entropy method consistent reduction and uncertainties solution designed for comprehensive methodological support of the entropy-comparator conformity quality system objects assessment of any nature safety requirements (fig. 2).

Logical transformation core is given by relations graph of the component state criteria for ξ and η (fig. 2) [6, 7].

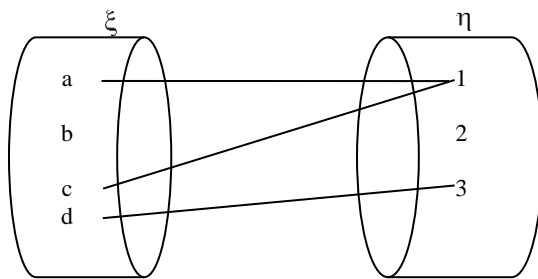


Figure 2 – Graphic scheme core linear logical transformation $K(x, y)$

Providing environmental and economic analysis of the system object ξ due to its complexity and multiple ties with environment gets into the uncertainty situation by the evaluation criteria: economic development level (a – economical system), socio-economic index society well-being (b – socio-economic system), environmental level (c – ecological system), population health assessment (d – social system). Available informational inaccuracies, absence proposed to supplement by the relationship function, for example, existing general information on economic (1), social (2) and environmental (3) quality indicators (see fig. 2). For getting data about ξ introduced linear-logical transformation core by providing a general quality assessment for ξ , which takes into account all evaluation criteria, that is, have a connection and the final result taking into account the information by η :

$$K(x, y) = (x^a \vee x^c) y^1 \vee x^d y^3;$$

$$Q(y) = \exists x \in \{a, b, c, d\} \left((x^a \vee x^c) y^1 \vee x^d y^3 \right) \wedge P(x) =$$

$$= \exists x \in \{a, b, c, d\} \left((x^a \vee x^c) y^1 \vee x^d y^3 \right) \wedge$$

$$\wedge (x^a \vee x^b \vee x^c \vee x^d) = y^1 \vee y^3.$$

As $K_1(x, y), K_2(y, z), K(x, z)$ are rectangular matrices, then the conjunction of predicates is considered as a product of matrices:

$$K(x, z) = K_1(x, y) \cdot K_2(y, z) = \bigvee_{y \in N} (K_1(x, y) \wedge K_2(y, z)).$$

Proposed a number of information technology for integrated complex systems safety analysis, designated improvement areas in case of information and methodological support formation for natural and man-made objects comprehensive quality assessment.

Established scientific and practical principles methodological, informational support complex systems state measurement and their functionality, investigated objects safety level based on usage of knowledge-based information systems obtaining knowledge by the study object results at “state (system – environment) – changes – process – system state”.

Developed algorithmic approach for object comprehensive analysis in whole, with its microstructure, which proposed to refer not only components and object system and operation processes. In systematic analysis introduced unique continuous real objects variables display for which the entropy is infinite, via information function (see. fig. 1).

According to provided methodological support information entropy function is introduced to establish the information uncertainty degree, ie the lack about system and its dynamics state information.

Proposed to avoid uncertainty in solving system socio-ecological-economic content objects environmental safety level assessment due to using mathematical logic structural models, combining state analysis and processes in systems, interacting with the environment: entropy state assessment and processes, quality level comparator identification (safety, environmental).

In a detailed system objects study based on their hierarchical structure resulting entropy function is perceived as uncertain behavior not well-ordered system of any dimension. To assess natural territorial complexes state applied thermodynamics, physical, informational entropy to determine environmental quality level for complex objects by only inconsistency measure environmental safety boundaries disparate systems and processes in them: maximum entropy production for one conditions group (ξ) compatible with its minimum for other (η):

$$S(\xi|\eta = y_j) = -\sum_i p_{ij} \log_2 p_{ij}, \quad (2)$$

$$MS(\xi|\eta) = -\sum_j P(\eta = y_j) \sum_i p_{ij} \log_2 p_{ij}, \quad (3)$$

where $S(\xi|\eta)$ – conditional entropy η at $\xi = x$;

$MS(\xi|\eta)$ – mathematical expectation of conditional entropy with variable ξ [8].

Adopted entropy adherence function for investigated system objects and determines deviation state level object component and its overall from equilibrium, homeostasis “system – environment”, which presented information about danger on any grounds.

The information space concept, system analysis related with conceptual study object model definition under scenario and target approach in order to create knowledge-based systems to it safety situation assess and sustainable development. The information and software

develop approaches for solving complex tasks in complex heterogeneous objects assessment for their operation compliance with the environmental safety requirements was analyzed.

Developed the informational-software for practical application ecological safety level integrated assessment methods which based on entropy and information approaches by awareness monitoring data.

Information part formed for system formation state assessment in knowledge-based systems form. Within

information and methodological support developed knowledge base on existing data basis about the system, additional information obtained as a result of uncertainty removal provided complex system low level investigation. New data obtained as a final result consistent uncertainties decrease at detailed scheme study “state₁ – process – state₂” applying state system formation “object – environment”, with phased complex methodological and information support implementation in complex systems quality assessment (fig. 3).

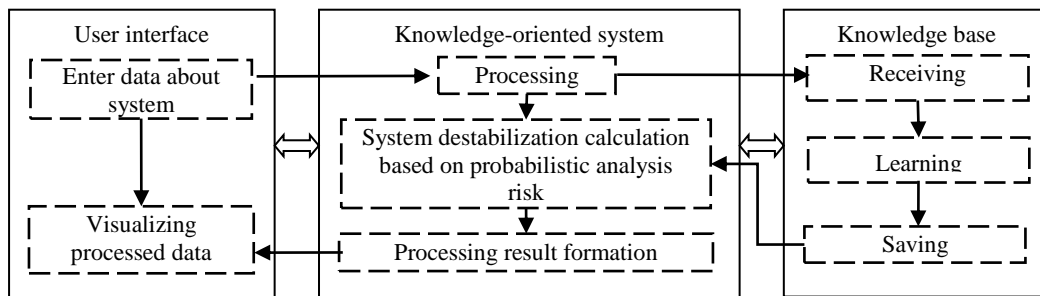


Figure 3 – General scheme of knowledge-oriented information system

In practice, the proposed information and software implemented for the comprehensive analysis results on the entropy-information based complex objects study, given the practical environmental safety evaluation results for

natural and industrial objects (Zmiev district, heat station), environmental and economic systems (Zmiev district – population health system) and operative safety control man-made objects based on Android (fig. 4) [9].

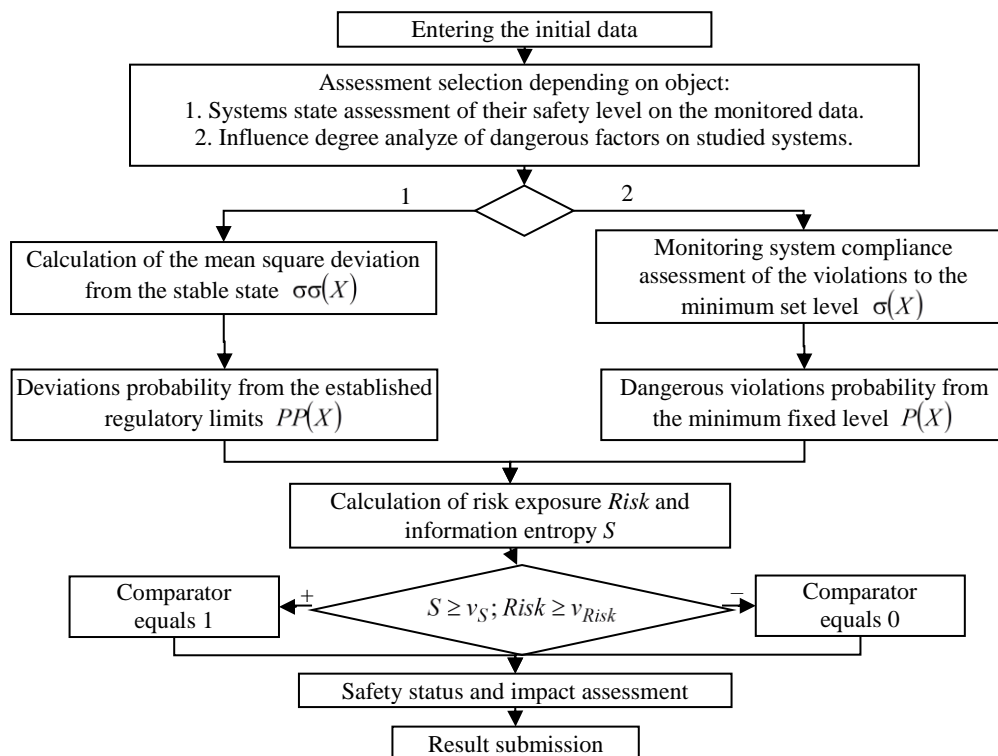


Figure 4 – Algorithmic provision of information-system assessment of environmental safety level by complex methodological support

Introduced comprehensive complex objects safety evaluation system is realized in practice in natural and man-made complex safety analyzing in Zmiev district landfill monitoring studies, whose territory is affected by industrial and energy differs significant accumulation of heavy metals (HM) in soils and appropriate level health (fig. 5) [6, 10].

At the micro level of complex system analysis to ensure proposed methodological approaches implementation to assess object level safety which is considered at example of factors restoration estimation attainable children with cerebral palsy state capacity (fig. 6) [9, 11, 12].

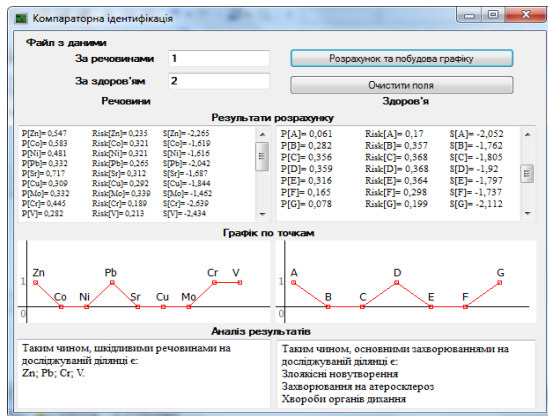


Figure 5 – Ecological safety level assessment of the soil and population health state

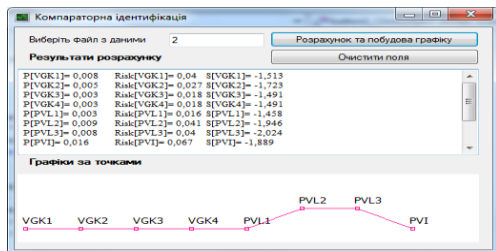


Figure 6 – Program evaluation of stabilization state factor of children cerebral palsy patients: PVI – periventricular ischemia; VGK1, VGK2, VGK3, VGK4 – intragastric hemorrhages (I, II, III, IV stages); PVL1, PVL2, PVL3 – periventricular leukomalacia (I, II, III stages)

The mobile devices oriented software that functioning on operating system Android, for continuous security processes monitoring on the example selecting effective treating sludge water means at coal-concentrated industries (fig. 7) [13].

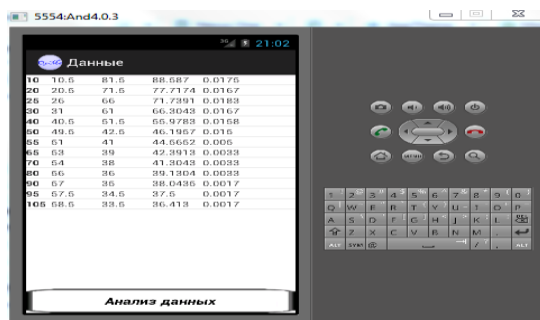


Figure 7 – Deposition process state determination according to the experimental data

Conclusion. 1. The information and methodological support comprehensive analysis of the environmental safety of objects based on entropy and information awareness approaches of monitoring data. Algorithmic implementation of methodological support software for quality evaluation of complex systems-level research “state (system – environment) – process – system state” is proposed.

2. Analyzed approaches in developing information and software support for solving complex tasks of heterogeneous complex objects accordance assessment to their environmental sustainable development operation and environmental safety requirements.

3. The software was developed for continuous environmental safety monitoring in terms of anthropogenic impact areas, the unstable system state, management and selection of effective production processes according to the provided comprehensive analysis and assessment of diverse complex systems and dangerous situations.

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