CREATION OF A COMPUTER-BASED ENVIRONMENTAL MONITORING SYSTEM

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Annotation. *Environmental problems have become almost the most pressing today. The dynamic development of natural resources and the accelerated development of production technology led to an increase in human material well-being, but also contributed to the deepening of the ecological collapse. To solve emerging problems, it is necessary to promote the balance of environmental safety and economic efficiency of the entire national economy.*

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Introduction. Over the past decade, the scale of anthropogenic and man-made impact on the environment has generated enormous negative responses in the ecosystem. Uncontrolled anthropogenic impact on nature significantly pollutes the human environment, clean drinking water, food, negatively affects the health of the population, and contributes to the emergence of zones of ecological crisis. The task of reducing environmental risk, increasing the level of environmental safety, and reasonable management of the environmental situation is becoming the main task.

Scientific and technological progress has a very negative impact on nature. Environmental pollution from industrial complexes is causing concern to environmentalists. The problem of environmental protection is relevant for all industrialized countries. In this situation, large-scale and effective monitoring of the state of nature in megacities, at environmentally hazardous facilities is needed to ensure environmental safety and sustainable development.

Up-to-date information about the state of the natural environment is needed

for a comfortable life, sustainable farming, construction, and emergency situations. Changes in the state of nature occur under the influence of natural processes and negative human activity. The need to forecast anthropogenic changes in nature is an extraordinary task.

The world regularly monitors climate change. These are meteorological, phenological, seismological and other observations of the state of the environment. The range of observations of nature is expanding, the number of measured parameters is increasing, and the number of observation stations is increasing. Environmental monitoring systems are becoming more complex every day[1].

Materials and methods. Solving the problems of analyzing environmental situations, assessing the ecological state, as well as creating computer-based systems for environmental monitoring and forecasting should be implemented on the basis of mathematical modeling describing the features of environmental processes.

An ecological system is a complex system based on the following characteristics:

- a set of interrelated and interacting elements;
- multi-factor goals.
- interaction of various subsystems;
- management of information, energy, and material flows in the system;
- random and non-quantitative nature of changes in factors;
- interaction with the external environment.

An ecosystem is a self-regulating complex that strives to achieve a stable state. The presence of direct, internal, or external feedbacks makes this possible. Self-regulation based on negative feedbacks is complicated by secondary reactions and extreme impacts on environmental objects.

With the help of system ecological analysis, it is possible to predict with a certain probability the nature, scale and forms of interrelations and interactions in ecology, analyze the sustainability and adaptation of various environmental objects. The tools of system environmental analysis are usually used in physical and

mathematical modeling, optimization methods, set and transformation theory, and other methods[2].

Today, there are a variety of forecasting methods. They differ in their quantitative and qualitative nature, reliability, accuracy, mathematical apparatus, characteristics of the forecasting object, and other methods used. In the process of development, regularities were formulated based on the analysis and generalization of object forecasting methods.

As you know, production affects a wide range of natural components: noise, vibrations, harmful emissions into wastewater and atmospheric air, a large amount of waste in the form of extracted rocks associated with the deposit, etc. A monitoring system based on environmental modeling helps to prevent or reduce the consequences of non-standard, as well as emergency situations accompanied by the release of pollutants. To get an accurate description of the environmental situation, you need to have an adequate model that reflects the ecological state of the object. The effectiveness of environmental modeling is determined by identifying and predicting the environmental situation based on the analysis of environmental information. This problem is successfully solved by methods of mathematical modeling of environmental safety.

Mathematical modeling of ecological systems and processes is a scientific field with an effective knowledge of environmental processes in the surrounding world, which allows you to approximate the practice of managing these processes. Moreover, mathematical modeling and experimental observations complement and develop each other.

The use of system environmental analysis methods is necessary to study the nature, form and scale of environmental relationships, analyze the sustainability and adaptation of environmental objects. Ecological models are complex systems. Building environmental models is a very difficult process.

The use of new production methods, the development of environmentally friendly waste disposal methods, and the transition to waste - free technologies are the main directions for reducing the negative impact of man-made complexes on the

environmental situation. In addition, it is necessary to study its impact on the environment and solve forecasting problems based on the use of environmental models and environmental modeling methods. Consideration of environmental problems from the point of view of their representation as an object of modeling implies solving the problem of system environmental analysis.

Mathematical modeling methods are used to quantify the dynamics of ecosystems. The model is simplified compared to the original, but reflects its specific properties. According to the method of construction, models are divided into: material and ideal[3].

Material models are used in the design of large industrial complexes that are associated with the transformation of nature. Models of structures are made in laboratories, and the processes that occur during programmed actions are studied. These models are used for technical purposes, but they are not suitable for solving environmental problems. Therefore, ideal models are of great importance for ecology: mathematical, graphic, simulation, and conceptual models.

Graphical models areflowcharts that reveal the dependence of processes in the form of graphs and tables.

Conceptual models are flowcharts that simulate the effects of subsystems and processes in large systems.

Conceptual and mathematical models are of great importance for ecology.

A conceptual model is a variant of a more formalized and systematized version of the traditional natural science model of the ecosystem under consideration, which consists of scientific texts, flowcharts, tables, graphs, and other illustrative materials. The purpose of a conceptual model is a generalized, clear and complete representation of the scientific concept of the system under study by certain means.

An energy or biochemical conceptual model is a block diagram of substance flows, trophic relationships in an ecological system, which are explained by text, tables, and graphs that reveal the composition, structure, and certain aspects of ecosystem functioning.

The advantages of conceptual models are considered to be universality, flexibility, a variety of means of expression, etc., due to which they can be applied to different systems, but they also have disadvantages: a high degree of ambiguity of interpretation, static nature, which make it difficult to describe processes in dynamic systems.

3 groups of mathematical tools can be used in environmental modeling: set and transformation theory, matrix algebra, difference and differential equations. Set and transformation theory can be used for models of various properties. The study and classification of ecosystems based on it creates various models of state changes that indicate qualitative states that are likely for the ecosystem, transition rules that determine the next state for any given one. Statistical and probabilistic models are considered to be the most adequate to the nature of ecosystems and reflect the influence of random factors on the ecological situation.

The first type of models is based on the fundamental laws of the material world (the laws of conservation of energy, mass, quantity of motion, transport, transformation, etc.). A research selection of significant laws for a particular object is carried out, their formalized recording is carried out, equations are solved, and the obtained solutions are interpreted, and models are verified.

These models contain information that is contained in the structure of the mathematical model itself (such as a differential, integral, balance equation), as well as information that is contained in the model parameters, determined from experiments. It should be borne in mind that the lack of experimental data on coefficients in the study of solutions to mathematical equations of the model allows you to get better results. Note that the models obtained in this way can be complicated due to multi-dimensionality, multi-factor nature, variety of boundary and initial conditions, environmental specifics, and other factors.

The difficulty in this approach lies in the discrepancy between the simplified model and its realistic image and in the difficulty of presenting a realistic image of a model with many parameters. It is also impossible to predict the impact of unexpected factors in the real ecological situation, which significantly complicates

the formation of plausible hypotheses.

The result of overcoming such difficulties is the second type of models, which is based on the regularities of ecosystem functioning by detecting relationships in these systems. A method of statistical analysis is selected for model development, designing the process of obtaining control data, compiling environmental data of the system, constructing an algorithm, and computing statistical correspondences. Diversification of the pattern of formation of the ecological situation requires repeating the described process, but in a different capacity.

Statistical definition of a mathematical model is the selection of the type and definition of model parameters. Moreover, the desired function can be not only single-factor, but also multi-factor. Choosing the type of model is an informal task, because the same relationship is described with the same error by different regression equations. The appropriate choice of the model type is justified by a number of criteria: compactness, interpretability, etc. Calculating the parameters of the selected model is basically a formal problem that can be easily solved by computer tools.

When a statistical hypothesis of a particular ecological system is formed, a database is needed, which, however, can be extremely large[4]. For a more realistic view of the system, it is necessary to separate non-essential information, i.e. you need to reduce the type and amount of data. Factor analysis is one of the methods for compressing environmental information. Data reduction is performed by the method of least squares, principal components using, for example, cluster analysis. It should be noted that primary environmental information has the following features: multidimensional data, non-linearity, ambiguity of relationships in the system, measurement error, influence of unaccounted factors, spatial and temporal dynamics. Mathematical models that take these factors into account make it possible to describe ecological processes more accurately.

It is reasonable to use linear and non-linear mathematical models to solve environmental problems, because the main part of environmental regularities is poorly studied. As a result, the multi-dimensionality of the simulated relationships

and their non-linearity are taken into account.

Very important in statistical modeling is the use of a priori data established in the process of solving various regularities of the model, and their possible number is reduced.

The identification of regression model parameters is usually obtained by the least squares method, the principal component method, and their derivatives.

The need for long-term forecasting of the behavior of complex ecosystems using computer technology has led to the creation of a new type of model – a simulation model, which includes the first type and the principles of constructing models of the second type. The essence of simulation modeling is the study of a complex mathematical model by performing computer experiments and processing the results. Computer simulation makes it possible to reproduce the cause-and-effect relationships of ecological processes and phenomena, allows you to study the behavior of complex ecosystems both theoretically and to study various strategies for regulating the environmental situation.

To date, the most effective method for constructing models of ecological systems is the method based on the use of fuzzy set theory. Models based on the fuzzy set theory make it possible to take into account the uncertainty and fuzziness of the initial environmental information of the modeling object[5]. Models based on fuzzy logic, taking into account the hierarchy of the object, can significantly simplify the environmental model, as well as ensure its adequacy in conditions of uncertainty. The construction of models takes into account problems that cannot be formally described due to the fact that some of the parameters are inaccurately or qualitatively specified values. Traditional methods are not suitable for solving such problems because they cannot describe the resulting uncertainty. The use of fuzzy logic allows you to build a new generation of knowledge bases and expert systems that allow you to store and process inaccurate information about an environmental object. Systems based on fuzzy logic can be used to assess the degree of impact of negative factors when information about an environmental object is unclear. Fuzzy models make it possible to describe ecological processes more adequately and fully

with initial fuzzy information, and also reduce the probability of erroneous decisions in environmental monitoring and forecasting.

When developing mathematical models for a computer-based environmental monitoring system, it is also necessary to take into account the geographically distributed affiliation of the modeling object[6]. From this point of view, objects can be divided into four levels.

World-class objects. Models of objects at this level should take into account the problems and features of environmental processes that are relevant to several countries. For example: air basins, world oceans, transboundary rivers, outer space, animal and bird migration, etc.

State-level objects. Models at this level should take into account large territories, large economic potential, basic enterprises, and resources. Technogenic complexes of the state ensure the independence and security of the country. The ecological safety of these complexes is equated with the ecological safety of the country, and "sustainable" development of the industry and the state is possible in a rationally organized natural and economic space.

Local-level objects. Models of this level should take into account the assessment of natural wealth, focusing on knowledge-intensive and high-tech industries, resource-saving technologies, complex extraction of valuable components from natural resources, utilization of man-made and secondary raw materials, reducing the share of raw materials and increasing the final competitive products, as well as other means of reducing the pressure of the environmental situation on the natural environment and

Объекты Local-level map items. Models should characterize the organization of territorial production units of production and highlight local problems with debilitating and polluting impacts on the environment, external negative impacts on nature and production[7].

Results and their discussion. Rationally selected mathematical models for the purpose of creating an environmental monitoring and forecasting system together with the use of modern information technologies that allow collecting,

processing and storing information about the functioning of an environmental object allow for effective monitoring and management of the environmental situation.

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