System Analysis in Assessing the Ecological Safety of the Urban Environment

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Abstract. This article discusses the issues of ensuring environmental safety in the territory of industrial cities. The structure of the system analysis of the ecological situation of the city is described. The urban environment is presented as a complex system consisting of the following subsystems - the state of atmospheric air, the state of surface and underground natural waters, the quality of drinking water, the state of the soil cover, noise and radiation conditions. These subsystems are considered by the authors as separate systems that include elements of a lower level. The factors influencing the state of these elements are formed, their mutual connection is tracked. Based on the results of the system analysis, the authors proposed a logical-probabilistic model of the environmental safety of an industrial city, the practical implementation of which will contribute to the sustainable development of the urban ecosystem.

1. Introduction

There is no doubt that at present a comfortable and safe human existence depends on the state of the urban environment. The unfavorable environment of the natural environment contributes to the emergence of a number of "environmentally related" diseases and a decrease in life expectancy. Therefore, today the problem of protecting and restoring the environment has become one of the most important tasks of science, the development of which takes place as a result of an increase in anthropogenic load and intensively developing technical progress throughout the world. The pollution of industrial cities is one of the most serious environmental problems.

The methodology for solving such problems should be based on an analysis of not only existing, but also possible risks, which will help determine the degree of protection of society and the environment. Thus, speaking about the ecological situation of the urban environment, it is necessary to identify the factors of direct influence on its state - this is the state of air, water, soil, radiation, geostucture, natural and climatic conditions. The lack of data on the complex impact of such factors of environmental pollution in an industrial city does not allow local authorities to effectively carry out environmental and sanitary and hygienic measures to protect the population. Only a general analysis of the risks of the impact of these factors is an effective method for assessing the environmental safety of not only individual cities, but also regions as a whole. Therefore, this issue is relevant, and its consideration opens up the possibility of a practical solution not only to the problems of protecting the natural environment in cities, but also to predict its further development.
Thus, our goal is to highlight the elements that affect the ecological safety of the urban environment and trace their interrelation, as well as present the factors affecting the ecological situation of the urban environment in the form of a system, which will allow us to identify the most acute problems that require immediate solutions.

2. Materials and methods
Analysis of existing methods and approaches for modeling complex systems in solving problems to determine the existing ecological situation of the urban environment showed that mathematical and "structural-hierarchical space-time" modeling [1, 2], fuzzy stochastic approach [3], methods of the theory of sensitivity and orthogonal decomposition [4], analysis of hierarchy and theory of fuzzy sets [5]. These methods make it possible to assess the “risk of environmental and economic damage from anthropogenic impact on the environment” [1], the evolution of the environment and determine the degree of environmental risks [2], a comprehensive assessment of the risk of groundwater pollution [3], “tendencies in the behavior of the system under different climatic data ”[4], predict environmental risks [5].

This analysis showed that there is a shortage of methods for quantitatively assessing the level of environmental safety of a city based on the concept of environmental risk. And this is when the logical-probabilistic approach has already found an active application, which allows you to systematize all influencing factors and bring them into an integral system.

Let’s imagine the city as a system, which is represented by the interaction of the urban ecosystem, technical, socio-demographic and socio-economic subsystems.

In turn, the urban environment is also a complex system that includes the following subsystems - atmospheric air, surface and underground natural waters, drinking water, soil cover, noise and radiation conditions. At the same time, it is necessary to take into account that the natural environment and anthropogenic activity are in an indissoluble unity, forming a certain “nature-society” system. Human activity forms the natural environment of the urban area, which subsequently affects human life and health. This relationship between society and nature cannot be assessed without an integrated approach to it. Thus, as a necessary condition and means of understanding human activity and its interaction with the urban environment, we will use system analysis, which has found application in solving such problems [6-11].

Systems analysis is research aimed at studying the special characteristics of complex objects, the variety of connections between elements, their quality and subordination. The use of this method allows you to build a holistic view of the subject under study. System analysis can be considered as the main method for assessing the level of the ecological situation of the city.

To solve problems in assessing the level of environmental safety of an industrial city, it is necessary to have a clear understanding of the urban environment as a system. The use of decomposition will allow you to divide the system into parts for detailed study. If difficulties arise at this stage, then it is necessary to revise the representations of parts of the system.

If there are no difficulties, an analysis is carried out for a detailed presentation of the system under study, i.e. each such part is already considered as a separate system, which makes it possible to determine the factors of influence on each system and trace their relationship. This allows you to build a model of the system. At this stage, the inaccuracy of the general or detailed presentation may be determined, then it is necessary to return one or two steps for revision.

The implementation of the proposed model, which will make it possible to move into a quantitative assessment of the factors influencing the urban environment and identify the most pressing problems for the formation of proposals for their solution. At the stage of making managerial decisions, additional elaboration or a change in the detailed presentation of the analyzed system may be required.

The application of this approach to conducting systems analysis allows replacing the solution of one main problem with the solution of smaller, simpler and interrelated problems.
3. The ecological situation of the urban environment as a complex system

The ecological safety of a city directly depends on the urban environment surrounding a person, which is formed by the state of atmospheric air, surface and underground natural waters, the quality of drinking water, soil cover, noise and radiation conditions [12-15].

The state of each of the presented subsystems will be considered as a separate structure performing some functions, which interacts with other systems as a whole, consists of continuously acting subsystems of a lower level. Such subsystems include the effects of transport, industrial enterprises, agricultural activities, production and consumption waste.

Each such subsystem is formed by elements of an even lower level. Let's consider them in more detail:

- transport:
  - automobile;
  - railway;
  - air;
  - water (sea and river);
- industrial enterprises:
  - light industry;
  - metalworking;
  - mechanical engineering;
  - oil producing and oil refining industry;
  - chemical industry;
  - pulp and paper industry;
  - food industry;
  - non-ferrous metallurgy;
  - ferrous metallurgy;
  - heat power engineering;
- agricultural activities:
  - animal husbandry;
  - crop production;
- production and consumption waste:
  - landfills for solid waste;
  - industrial waste landfills;
  - authorized landfills;
  - the formation of spontaneous dumps in unauthorized places;
  - mothballed landfills;
  - mothballed industrial landfills;
  - other facilities (sludge ponds, sludge ponds, accumulators of liquid and pasty waste and other waste disposal facilities owned by enterprises).

In addition, each such subsystem includes lower level elements that are interconnected. Such connections form a set of elements into an integral system. So, for example, speaking about the influence of road transport, a complex system is meant, which includes:

- elements that have an impact in the form of environmental pollution;
- measures to reduce the negative impact.
- The elements of negative impact include:
  - emission of exhaust gases;
  - abrasion of tires;
  - the intensity of the use of vehicles;
  - wear and tear of highways (dust, wear of road marking lines into lanes, etc.);
  - gas stations;
  - work of auto repair enterprises;
work of an asphalt concrete plant;
operation of road equipment bases;
the occurrence of an accident involving vehicles.

Measures to reduce the negative impact include:
the use of vehicles with the ability to use electric motors;
the use of cars that can use natural gas as a motor fuel;
sanitary breaks from roads;
quality of road improvement;
reducing the concentration of exhaust gases in green spaces along the road;
environmental protection measures during the work of auto repair enterprises;
environmental protection measures during the operation of the asphalt concrete plant;
environmental protection measures during the operation of road equipment bases.

The presented elements include a list of characteristics that influence each system of the natural environment, forming systems of the last level. These characteristics serve as criteria for assessing the impact of each factor on the general state of the urban environment.

At the same time, it is necessary to take into account the existence of sources of influence of natural origin - meteorological, geological, hydrological factors, etc. From this we can conclude that each system is not only exposed to the influence of many external systems in relation to it, but also itself influences them.

4. Results and discussion

Based on the results of the system analysis, a logical-probabilistic model of the ecological safety of the urban environment was built. The model makes it possible to assess both the state of atmospheric air, soil cover, natural water bodies, sources of drinking water, noise and radiation conditions, and the threat posed by them to the urban environment that requires a response in order to reduce the risk - an environmental challenge. The constructed model of the system includes 1355 interconnected elements, including 885 factors that influence the formation of the level of ecological safety of the urban environment.

These factors are presented in the form of elements that have a negative impact - sources of pollution, and elements that reduce or prevent such impact - environmental measures. Since the elements of the logical-probabilistic model affect each of the subsystems simultaneously, their influence is subjected to logical addition. But at the same time, the model takes into account the "neutralizing" relationship of pollution factors and measures to reduce them, in this case, logical multiplication is applied. This approach will help build a holistic view of the existing environmental situation in the city.

5. Conclusions

In this work, as a necessary condition and means of understanding human activity and its interaction with the urban environment, system analysis is applied. This made it possible to consider the urban environment as one large system, consisting of systems of lower levels, to identify the elements that affect the ecological safety of the urban environment and to trace their relationship. A logical-probabilistic model of the ecological safety of the urban environment has been built. When translated into a quantitative assessment of the factors influencing the urban environment, the proposed model will help identify the most pressing problems, assess the effectiveness of existing environmental protection measures, and form new management solutions to the identified problems. This will allow assessing the existing level of environmental safety of the urban environment and predicting the further development of the city.
6. References

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