GEOINFORMATION SYSTEMS AND REGION ENVIRONMENTAL PREDICTION

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ABSTRACT

Prediction models and methodological developments in Geographical Information Sysmems (GIS) for regional analysis and predictions of environmental states are considered. The complex and interdisciplinary nature of environmental problems requires the development of a new class of GIS, integrating the mathematical models, databases and expert knowledge based on a conceptual model. It is known that chemical contamination is one of the main factors of the environment pollution of regions. Therefore the new environmental quality index taking into account the chemical contaminants parameters is created for solving the region environmental problems. A region environmental zonation procedure was developed, which uses an arbitrary number of environmental arameters. An approach to identifying of environmental danger zones in a region territory was developed. The zones are represented on computer map of that region. A GIS-technology scheme for predicting Environmental Danger Zones (EDZ) changes is discussed. The scheme is based on using an analysis of the region's economical development scenario. Samples of regional environmental prediction for Siberian region are given in the paper.

KEY WORDS: Geographic Information System, conceptual model, regional environmental modelling, economical development scenario, ecotoxicological danger

INTRODUCTION

Humanity enters into crisis stage of the world development, when unlimited economical growth leads to global changes of the biosphere. It puts the question not only about increasing the life level of people, but about existence of the humanity on the earth. Essential decisions of regional and global environmental problems, as it was declared at United Nations Conference on Environment and Development in Rio (1992), may be achieved only by conversion world civilization into a society of sustainable development. Criteria and ways of future development may be defined out with help of the Geographical Information System (GIS) using the modelling for predictions of region environmental states based on the analysis of a region's economical development scenario.

In the modern world, the successful social and economical development of regions and the solution of environmental problems needs a new approach to the control of a territory in terms of regional sustainable development. At present, chemical pollution is one of the main factors of biosphere degradation of Russian egions which is a result of irrational human activity. It is known modern industry produces thousands of new chemical substances every year, many of which pollute the air, water, soil. Therefore region environmental predictions are needed to assess of ecotoxicological danger of such chemical substances.

The solving of regional environmental prediction problems is interdisciplinary in nature. It is based on a large volume of heterogeneous environmental and economical information of both qualitative and quantitative types. So the geographic information systems integrating the mathematical prediction models, databases and knowledge bases are one of the prospective instruments for regional environmental problems solving. But qualitative information must be stored in GIS knowledge base and used for the prediction models. This paper is devoted to consideration of some regional problems related with environmental prediction using GIS.

Construction of GIS for regional problem solving needs is a new approach to regional environmental prediction. Our approach is based on using of Environmental Danger Zones (EDZ) identified in a region's territory. The idea of this approach to environmental prediction is to estimate a change tendency of a region's environment state through the change of EDZ dimensions determined by analysing of the economic development scenario. Environmental danger zone is a part of territory in which environment quality indexs are oversteped the limits of allowed norms.

There are some important factors connected with region environmental predictions based on EDZ:

1) creation of the mathematical model, to take into account both the scattering of the pollutants in air, water and other environmental parts and ecotoxicological danger of chemical substances brought into environment by industrial enterprises;

2) development of a complex environment quality index which accounts for an arbitrary number of environmental parameters and which will be suitable for revealing of EDZ;

3) creation of GIS-technology of region environmental prediction, which can be based on the procedures of computer experiments associated with the prediction model in GIS. Consideration of the methodological aspects of the problems is the main purpose of these paper.

METHODOLOGICAL ASPECTS OF REGIONAL ENVIRONMENTAL PREDICTION SOLVING

Generally, the environmental danger zones may be identified on the basis of knowledge about environment quality at specific points in a region's territory. The environment quality must be estimated by a value of the complex environment quality index (CEQI) which accounts for both the pollution ingredients' concentrations in different environmental parts and their ecotoxicological danger degree. In order to calculate a value of CEQI at points in a region's territory, it is necessary to use a mathematical model of the pollutants scattering in air, water and other environmental parts and a mathematical model of the pollutants' chemical structure for assessment of their ecotoxicological danger.

What about models for environmental prediction ? Mathematical models of complex objects may be divided into four wide classes: analytical, empirical, simulational and semiotic models.

1. Analytical models (AM) use theoretical knowledge about object of modelling. The most important features of the object are chosen for constructing the analytical model. So the AM are suitable for qualitative prediction of the object properties.

2. Empirical models (EM) are based on experimental data related to the object of modelling. They may be empirical - statistical or self - organized types. One type uses a large volume of data and statistical methods of data processing. A second type uses

methods of automatic classification and clusterisation for processing of small volume of empirical data.

3. Simulational model (SiM) represents the object properties in time by means of imitating of elementary processes and keeping of their logic and time structures. In common case SiM consists of algorithms set, has a graph structure and includes partical models (AM and EM) for representing of some elementary processes. SiM are used for prediction of object properties by computer experiments with the model. SiM are suitable for quantitative prediction.

4. Semiotic models (SeM) combine the quantitative and qualitative information about object using artificial intelligence methods. There are different types of semiotic models. In particular one of them is a simulation - linguistic model which is the most suitable for integrating quantitative and qualitative information about complex object. The simulation - linguistic model consists of two partial models. The first of them is the simulation model and the second partial model is a semiotic model of a logic - linguistic type. Models of these types developed for estimating the ecotoxicological danger degree of chemical substances are described in the paper below.

The interdisciplinary nature of regional environmental problems makes the models of the first and the second classes insufficiently effective for solving the problems. The third class of models is used most widely. The main disadvantage of the SiM for the regional environmental problems is the impossibility of accounting for the qualitative information about object, in particular, expert information based on experience and the intuition of experts. The models of the fourth class are more suitable for solving the regional problems.

Below some features of a procedure of the mathematical models creation for regional environmental prediction are considered (Polichtchouk, et al.,1996). The masses of chemical substances brought into environment by industrial enterprises are estimated by analysing of the region's economical evelopment scenario. Then output volumes of each enterprises are determined for each step of the prediction, in order to calculate the pollutants' corresponding masses produced by the relevant enterprises. The information is based on a complex environment quality index evaluation, using mathematical models, and accounts for both the scattering of the pollutants in air and water and ecotoxicological danger degree of the pollutants brought into air and water by the enterprises. The values of the complex environment quality index are used to reveal EDZ in the territory and for drawing of these zones on to the computer map of region by means of GIS. The degree of ecotoxicologic danger of pollutants is determined in quantitatively with help of an analogy model which is simulational one. Sometimes the degree is determined in quality type as "klass of danger". In this case the logic - linguistic model (LLM) is used. LLM is a model of knowledge about chemical substances, their structures and properties. It has logical and linguistic components. The logical component of the model is described by language of a predicates type. And linguistic component is represented by a grammatical linear code of chemical structures.

APPLICATION AND ORGANIZATION OF ENVIRONMENTAL PREDICTION

One of the important problems discussed in this paper is creation of GIS-technology of regional environmental prediction, oriented to the organization of a procedure of computer experiments with the prediction model in GIS. The GIS-technology involves a technological scheme of information processing and program means supporting technology. Below the set of information processing
stages is given:

1) obtainment and collection of environmental information and organization GIS database;
2) analysis of region's development scenario;
3) modelling of pollutants scattering in environment;
4) estimation of ecotoxicologic danger of a new chemical pollutants brought by enterprises in environment;
5) determination of complex environment quality indices;
6) determination of environmental danger zones in the region territory at each step of the prediction;
7) representation of environmental danger zones on the computer map of the region.

GIS software is intended to application of GIS GeoDraw/ GeoGraph and ArcInfo. Raster GIS developed for region environmental predictions uses data in formats DB and DBF and programming language C++ for creation of modelling programms.

References:

1. United Nations Conference on Environment and Development (1992) Rio de Janeiro.
2. Polichtchouk, Y.M., Tsipileva, T.A., and Salmina, N.Y. (1996) Modelling of the Structure of Chemical Compounds and Prediction of Ecotoxicological State of the Environment, Chemistry for Sustainable Development, 4, 219-229.