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РАЙОНИРОВАНИЕ ТЕРРИТОРИИ ТРАСС ТРУБОПРОВОДОВ ПО СТЕПЕНИ ОПАСНОСТИ ВОЗНИКНОВЕНИЯ АВАРИЙ СРЕДСТВАМИ ГЕОИНФОРМАЦИОННЫХ СИСТЕМ И ИСКУССТВЕННЫХ НЕЙРОННЫХ СЕТЕЙ

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Аннотация: описан метод районирования территории вдоль трассы трубопровода по степени потенциальной опасности возникновения аварий. Прогноз основан на многофакторном анализе, выполненном в интегрированной системе: ГИС и искусственных нейронных сетей (ANN) (программный комплекс «Advangeo»). В качестве объекта исследования был взят трубопровод на Северном Урале (Россия). В результате обработки исходных данных и обучения нейронных сетей была получена карта мест потенциальных аварий по трассе многофакторном анализе а. Результаты были сопоставлены с итогами математико-картографического моделирования в среде ГИС MapInfo.

Ключевые слова: районирование территории трубопровод, многофакторный анализ, прогноз, искусственные нейронные сети.

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Zoning pipeline routes according to the degree of danger of accidents using geoinformation systems and artificial neural networks

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Abstract: The article describes a method of zoning the territory along the pipeline route according to the degree of potential danger of accidents. The forecast is based on a multivariate analysis performed in an integrated system: GIS and artificial neural networks (ANN) (software package Advangeo). The pipeline in the Northern Urals (Russia) was taken as an object of research. As a result of initial data processing and neural network training, a map of potential accidents along the pipeline route was obtained. The results were compared with the results of mathematical and cartographic modeling in the GIS MapInfo.

Key words: zoning of the pipeline territory, multivariate analysis, forecast, artificial neural networks.

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Introduction

Pipeline logistics is the most efficient way of transportation at all stages of mining production. In the extraction of solid minerals, pipeline transport is used for the delivery of laying mixtures [23] to the place of laying [21], and in the extraction of hydrocarbon raw materials for its transportation to the place of processing [22]. Accidents at pipelines are one of the most serious economic and environmental problems of the gas industry [14], [18]. The most general analysis shows uneven distribution of pipeline accidents [4],[13]. Damage of a main pipeline is caused by two groups of factors. The first group is caused by a decrease of pipeline bearing capacity, the second –by increase of loads and impacts. Decrease of bearing capacity of oil pipelines occurs due to defects in the pipe wall, metal aging, and corrosion [1], [11], [17], [21]. Factors of the second group are caused by pressure, stress from the temperature effects of the pumped oil and the surrounding soil, the pressure of the soil layer above the pipe, various static and dynamic loads, earth surface deformations, seismic impacts [5], [20], [22]. Factors of the second group, listed above, are characterized by spatial reference and the need to process large volumes of different types of data in their evaluation [7]. For this reason, the analysis of this kind data requires the use of computer technology. A significant number of works are devoted to this aspect, considering from different points of view the problem of zoning pipeline routes territory according to the degree of accident risk by means of geoinformation systems and artificial neural networks. In particular L. A. Strokova and A. L. Ermolaeva [15] on the basis of GIS-technologies analyzed the main loads and impacts on the main gas pipeline from the influence of land surface subsidence caused by karst and thermokarst processes, and built schemes of territory zoning by degree of danger. However, this work did not take into account the degree of influence of individual factors on the results. In the work of V. A. Chikharev [19], the stages of creating a spatial database of the pipeline condition are considered and recommendations on optimization of geotechnical monitoring are given. However, the question about the degree of influence of each of the factors was not considered. In the work of A. N. Rasputin, V. A. Zhelobetsky, S. N. Kuimov and K. V. Postautov [12], solutions to optimize the system of diagnostics and control, technical and forecasting state of the main gas pipeline using GIS based on geological and geophysical information are presented. However, the issue of territory zoning was not considered. S. I. Bidenko [3] showed the possibilities of artificial neural networks (ANN) for processing and analysis of large arrays of geospatial data with obtaining testing errors depending on the accuracy and quality of training sets. However, this experience was obtained for specific coastal conditions and is not relevant to pipeline systems. S. A. Terekhov, N. N. Mukhamadieva, N. N. Fedotova, et al. [16] presented an approach to building an ANN for modeling a multi-parameter pipeline system, but the article lacks spatial reference of the object itself. The article by A. G. Osipov, V. V. Dmitriev, S. A. Maslennikov [10] describes scientific and methodological approaches to GISmapping modeling of pipelines based on spatial multiparametric analysis of the territory in order to choose the route of pipeline system in the model territory in the Arctic zone of Siberia. In the study the ranking of landscape properties according to their influence on the territory suitability, qualimetric estimations of suitability classes of natural systems and graph theory for determination of the optimal pipeline route based on the Dijkstra algorithm were used. However, the values of the weighting coefficients are subjective. Article by N. E. Mohammed [8] developed a framework for the integration of GIS and ANN for forecasting the development of social objects. GIS is used to collect, manage and query spatial data, and ANN is used for modeling. However, how this approach can be used for the zoning of the territory according to the degree of danger along the pipeline route is not clear. The above review of sources devoted to the problem under consideration confirms that the identification of hazardous areas of pipeline routes by means of GIS and ANN is relevant.

Methods of research

The Krasnoturyinsky district of the Northern Urals served as an example of integrated use of GIS and ANN technologies for zoning the territory of pipeline routes according to the degree of danger of accidents. The specified area is characterized by massive manifestations of accidents on the main gas pipeline. Within its limits, on the area of about 200 km2 in different years there were about 10 major accidents and more than thirty incidents , including repeated ruptures of pipes during their hydraulic tests. The area under consideration is intersected by a complex system of the largest geodynamically active faults, which separates hypsometrically contrasting differently leveled regions — the Ural Mountains and the West Siberian Plain [9]. The area is located within the ore node of non-ferrous metals, as a result of which an area alternating sulfidization of Paleozoic strata is observed. In addition, the presence of sedimentary hematite-limonite, sideronite and manganese ores in the marginal part of the Meso-Cenozoic cover of platform deposits is established. The area has a well-developed energy supply system, which includes long lines of powerful and heavy-duty power lines, which determine the electrolyte characteristics of geochemically saturated groundwater.

The following digital cartographic materials served as a working basis for zoning the territory: maps of power lines, highways and railoads, hydrography (Fig. 1, *a*); maps of active fault zones with indication of places of recorded pipeline accidents (Fig. 1, *b*); map of quaternary formations (soils) (Fig. 1, *c*); geological map and information on ore occurrences, allowing to judge about types of groundwater mineralization in different-age structural and formation complexes of ore areas (Fig. 1, *d*).

Identification of active faults and making a geodynamic map for their classification was carried out by special interpretation of a satellite image of scale 1:200,000. The revealed system of faults was compared with the hypsometric map of scale 1:50,000 and the results of morphometric analysis of the territory. The faults were divided into 5 categories according to their actual width on the ground: up to 50 m; from 50 to 100 m; from 100 to 150 m; from 150 to 200 m; and from 200 to 300 m. classification of faults according to their activity was carried out based on the visible vertical amplitude of the relative relief-forming spaces separated by geodynamic blocks. According to this feature, active faults of 5 categories are distinguished: with an amplitude of less

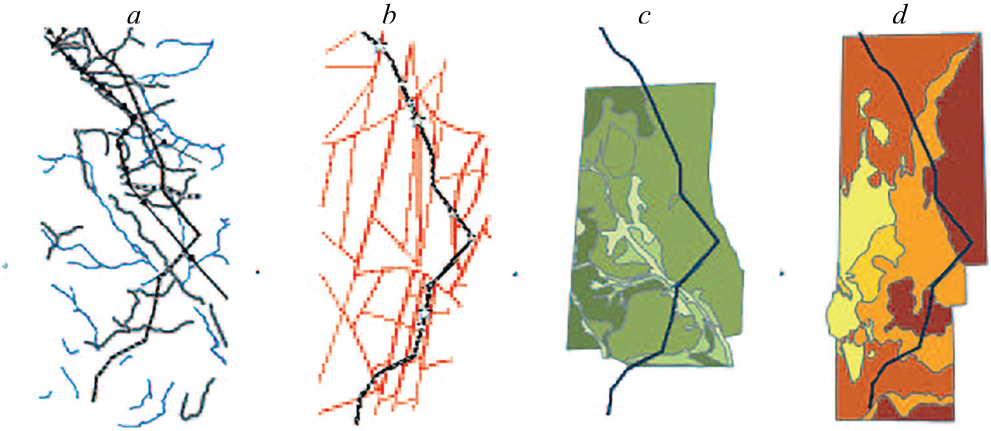

Fig. 1. Source materials: a — network of roads, power lines and hydrography; *b* — zones of active faults with indication of places of registered accidents on the pipeline; *c* — quaternary deposits (soils); *d* — rocks

than 10 m (within a block), 10 m, up to 20 m, up to 30 and more than 30 m (interblock). Each group of these values was assigned points of potential danger. The values of the specified parameters and their corresponding scores were entered into the GIS attribute tables. Based on the obtained results, a thematic map was created (see Fig. 1, *b*). The probable geochemical assessment of groundwater aggressiveness in zones of active faults consists of three factors. The first is the presence and type of ore mineralization in the geological complexes intersected by such faults. The second is the granulometric composition and genesis of loose quaternary formations containing pipelines. These soils contribute to maintaining the level of groundwater mineralization in the zones of in active faults or, on the contrary, cause its dilution. The third one is the proximity to power lines of different capacity. To account for the first factor, on the basis of the map presented in Fig. 1, *d*, the classification of rocks on the degree of their geochemical aggressiveness was carried out. The least dangerous in the area, apparently, are those of Paleozoic age. The type of rocks and the values of these points were entered into the GIS attribute table. Similar operations were performed to account for the second factor. The compiled digital map of Quaternary formations reflected the spatial distribution of individual differences. Based on the obtained map, classification of vertical sediments according to the degree of dilution of a level of mineralization of groundwater in zones of active faults was carried out. In total, taking into account the granulometric composition and the degree of saturation with surface water, four categories were identified, each of which was assigned a certain value of the potential hazard score. The type of quaternary formations and the values of these scores were entered into the corresponding GIS attribute table.

The software package Advangeo [2] was used to determine the location of potentially dangerous geodynamic zones. The complex was developed for modeling and analysis of spatial data using artificial intelligence. It consists of databases (DB) and GIS. Neural network model database parameters and metadata are stored in Microsoft SQL Server. The GIS component is an add-on to ESRI ArcGIS software.

The artificial neuron is the main component of the ANN. Neurons are organized in such a way as to facilitate data reception and processing (multilayer perceptron) from layer to layer. Through this process, the data is simultaneously evaluated and weighed. This is done in order to find the best fit to the data on which the network was trained, and which will give an accurate forecast. To calculate the output value, the weight (wi) may differ for each input signal (ai) and each activation function (g) (Fig. 2, *a*). Activation functions are often determined by a sigmoidal curve (Fig. 2, *b*).

The output signal of each neuron of the previous layer is the input signal of each neuron of the next layer. All inputs

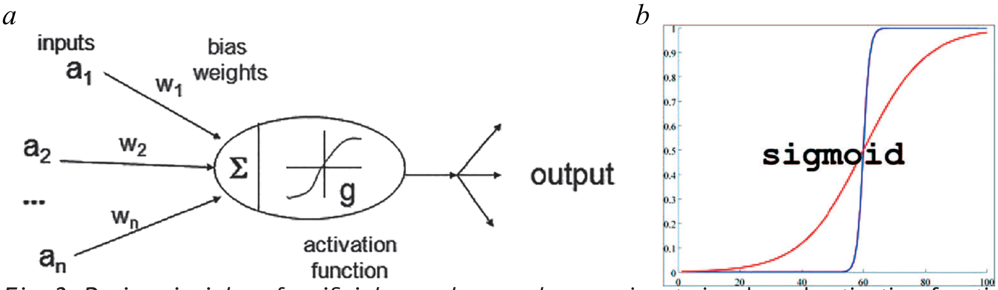

Fig. 2. Basic principles of artificial neural networks: a — input signals and activation function; *b —* sigmoidal curve

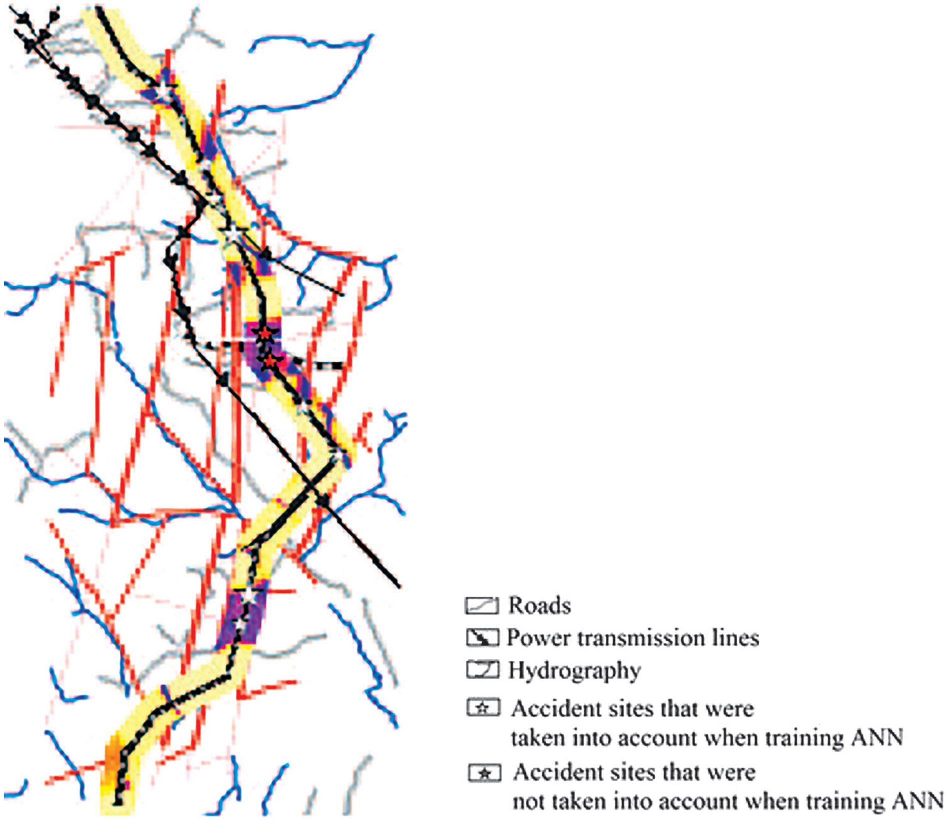

Fig. 3. Map of pipeline route zoning by accident hazard

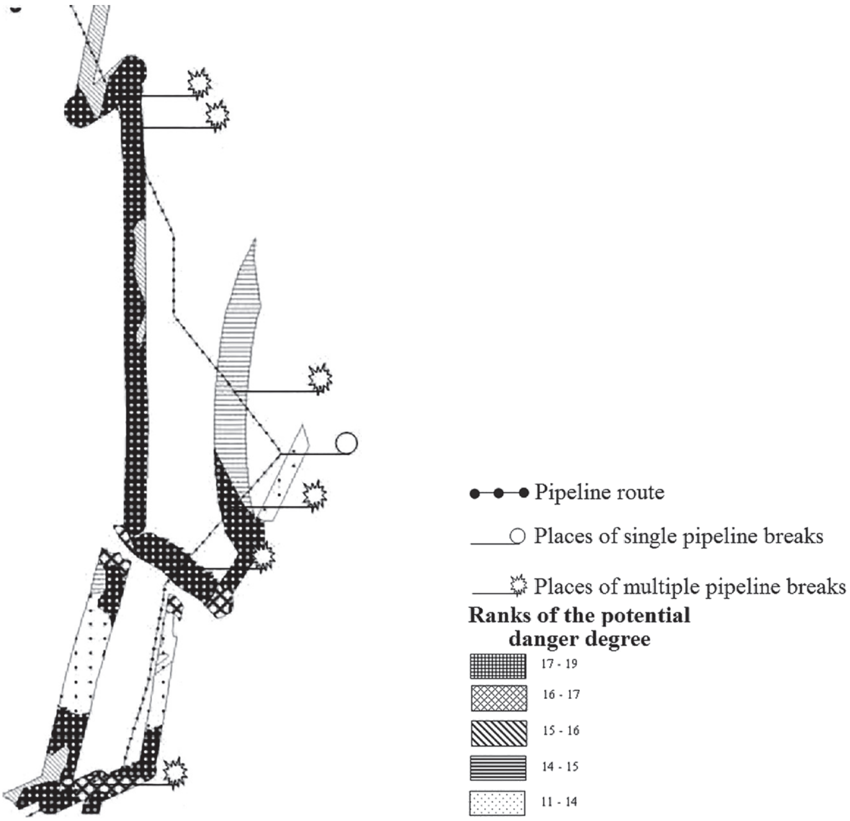

Fig. 4. Map of potentially hazardous zones in the vicinity of the pipeline route, built using GIS MapInfo

of one neuron are weighted and used to calculate the output signal. The number of layers and neurons in a layer can vary for each scenario. This type of network is called a multilayer perceptron. The results of Advangeo are: maps of the probability of occurrence of an event of interest (e.g., a pipeline accident) or maps illustrating a quantitative forecast of the parameter in question (e e.g., mineral content in rocks).

Results and discussion

As a result of overlay operations, a map of potentially dangerous zones is obtained (Fig. 3).

The obtained results fairly well agree with the recorded pipeline breaks, which which were not involved in the ANN training process (red stars in Fig. 3). In addition, the obtained results were compared with the results of mathematical cartographic modeling of similar zones of the same object using the GIS MapInfo. The results are shown in Fig. 4.

Conclusions

The results obtained show that the integration of GIS and ANN in the form of the Advance software package makes it possible to predict the zones of possible pipeline accidents and to differentiate the degree of danger within these zones. The approach presented above for identifying environmentally hazardous zones serves as the basis for zoning the territory through which the pipeline is supposed to be laid. The list of factors taken into account may be changed depending on the degree of importance of objects, their length, availability of necessary information, etc. Zoning of the territory along the pipeline route according to the degree of accident risk allows to tmake a decision on additional measures to protect the pipeline or make changes in the position of the future route in this section in advance, at the design stage.

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