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Software for risk assessment based on the data processing of monitoring the state of the Ground-Climate-Pipeline system

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Abstract. The paper considers various software for monitoring the state of the Ground-Climate-Pipeline System, namely GIS "Extremum" and PipeGIS. These two software packages are analysed, and their disadvantages are identified. Requirements are established for the development of new software for monitoring the state of the Ground-Climate-Pipeline System in sections with hazardous processes.

1. Introduction

On the territory of the Russian Federation at the end of 2019, according to the Federal State Statistics Service "Rosstat" length of pipelines used to transport oil and are in constant operation, is 53.4 thousand km [1].

During the operation of trunk pipelines there may be failures in their proper operation caused by the following events [2-4]:

- ingress of construction debris, land, pieces of wood, and other objects left in the pipeline by mistake after construction or repair;
- clogging of cleaning devices and failure of autonomous diagnostic devices moving with the oil flow;
- ingress and accumulation of small rock particles, as well as slag and small pieces of metal, left on the inner walls of pipes;
- formation of ice plugs as a result of freezing of water accumulated in low places that got into the pipeline during construction;
- influence of hazardous processes (HP) on the pipeline.

Despite some decrease in the number of accidents in the period from 2012 to the present [5], it is still possible to resume the growth, which is due to the aging of the pipeline network, climate, and the increasing length of pipelines. One of the important areas of reducing the risk of accidents associated with the disruption of normal pipeline operation is the development and implementation of special software [6-7].

The goal of this research is to define the requirements for the software designed for the timely detection of the possibility of malfunctions and assessment of the risk of accidents based on data processing of the monitoring of the Ground-Climate-Pipeline (GCP) system in the areas with HP [8].

2. Methods

To formulate the requirements, it is proposed to use the method of analysis and synthesis of the properties of the most developed software tools available on the market. An important selection criterion is the presence of functions that provide the risk assessment of an accident on the oil pipeline based on monitoring data. The method provides for the synthesis of useful properties of existing systems and their development using modern computer modelling tools.

There are various software tools designed for risk analysis and monitoring of the GCP system state, Table 1. Below GIS "Extremum" and PipeGIS software are reviewed and suggestions for their improvement are formulated [9-11]. The main technical requirements for software designed for risk assessment based on GCP system monitoring data processing are specified.

Table 1 shows that the reviewed software packages, each individually, do not have all the necessary useful functions. At the same time, software tools of GIS "Extremum" and PipeGis have significant areas of intersection of useful properties, due to the needs of pipeline operators. At the same time, some properties required for complex assessment of the pipeline condition, including ground, climate, and pipeline, are not present in any of the systems considered by the authors, which reduces their predictive capabilities [12]. In case of new development, it should be taken into account that the software containing the full set of the listed useful properties, including the proposed ones, will provide the competitive ability of the product and can be offered to the organizations operating pipeline systems [13].

3. Results

Analysis of emergency risk indicators in sections with HP is a complex task. In this regard, the authors propose the use of software that provides interaction between the forecast part and the monitoring subsystem, discussed in the article "Methods of monitoring the GCP system in sections with hazardous processes" by the same authors.

The considered monitoring subsystem is a set of software and stored in the memory data having a significant volume and complex structure, falling under the definition of BigData, obtained from a variety of sensors tracking parameters of pipeline sections as segments of the GCP system [14].

When assessing the risk of an accident on the sections of the pipeline it is important to predict the state of the GCP system, which is impossible without modelling the interaction of all elements of the system, which have spatial character. For each specified time period, the spatial distribution of the predicted parameters of the interaction of elements of the GCP system is conveniently presented in the form of a thematic map. On this map, it is important to show the areas where interaction parameters fall into intervals characterized as hazardous.

The advantage that provides visibility of the situation will remain with software tools that implement GIS technologies, as in such systems it is possible to map hazards and risk indicators. Maps allow analysing complex phenomena built on a significant number of parameters, which provides reliable forecasting of various hazardous events and accidents.

Therefore, the list of system requirements should include the use of GIS technologies. The GIS database will include terrain descriptions, design data, and monitoring materials. The following models should be formed from the listed elements:

- territory model (including geology and topography);
- pipeline model (including shut-off structures, looping, pumping stations, tanks, and energy facilities);
- hazardous process model;
- monitoring model, including communication facilities (wired and wireless), transport communications (located along the route) mode indication facilities, and emergency sensors.

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Table 1. Features of GIS «Extremum» and PipeGIS software.

Software	GIS "Extremum"	PipeGIS
Developer	LLC "Extreme Situations Research Centre" in concert with Bauman Moscow State University on request from All-Russia Scientific Research Institute on Problems of Civil Defence and Emergency Situations (VNII GOChS)	Company PROGIS Software GmbHa combination of an ICT & Consultant Company
Databases	Cartographic and attributive	Graphic, technical, and attributive
Simulation	• Conditions in the emergency zone • Consequences of accidents on oil pipeline systems • The actions of the rescuers	Conditions in the pipeline accident area
Assessment	• Accident damage size • Pipeline conditions	Pipeline conditions
Function	• Solving important tasks on prevention and elimination of emergencies (including on the pipeline) of natural and technological nature • Forecast of complex geological processes development • Pipeline condition assessment • Management decision making	• Monitoring and forecasting of pipeline accidents • Pipeline condition assessment
Risks	Development of complex geological processes	• The occurrence of HP on the pipeline (external and internal corrosion, damage of the pipeline, exceeding the standard stress-strain state) • The occurrence of HP in the environment (in the ground, in water basins, in the terrain) • The occurrence of HP in case of dishonest service (decrease in minimum depth of coverage, a decrease in the frequency of service)
System openness	no	yes
Disadvantages	• No systematic approach • Does not allow calculating the integral index characterizing the state of the GCP system	

The presence of these models provides an opportunity not only to fix current data but also to assess the possible state of the pipeline in the future. The forecast of various changes in the state of the GCP system is fixed as a risk map.

The risk indicators are calculated for each section within which the GCP system state remains constant [15]. When zoning with different conditional signs, it is proposed to display the following territories:

- (I) first-class territory – low hazard;
- (II) second-class territory – hazard;
- (III) third-class territory – extremely hazard.

Based on the hazard level of the territory, the software will offer various recommendations for risk reduction, linked to the terrain and the capabilities of services that provide security of the pipeline system.

According to the requirements for the software under development, the system should be open to changing the data describing the hazard levels, if necessary.

4. Conclusion

Thus, in this paper the requirements for software development are proposed, one of the tasks of which is timely detection of possible fault locations, as well as accident risk assessment based on the processing of data monitoring of the Ground-Climate-Pipeline system in sections with hazardous processes. The proposed software should include all functionality of the software tools considered by the authors, as well as additional functions presented in the research. The new software should provide a systematic approach to risk analysis.

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