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Research Article

SCIENTIFIC FOUNDATIONS OF INTELLECTUAL ANALYSIS OF HYDROGEOLOGICAL DATA

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ABSTRACT
This article presents the scientific foundations of intellectual analysis of hydrogeological data. Intellectual analysis of hydrogeological data helps in managing groundwater, ensuring its efficient use, and protecting water resources. Through intellectual analysis, the article outlines the identification of long-term dynamic changes in groundwater and the aspects of drawing conclusions.
Various methods of intellectual processing of hydrogeological data present effective approaches to data analysis and management. The process of enhancing the efficiency of intellectual processing technologies for data is highlighted as being of significant importance not only from a scientific but also from a practical perspective.

Keywords: *Groundwater, Intellectual Analysis, Intellectual Processing, Artificial Intelligence, Methods, Parameters, Forecasting and Hydrogeological Data*

INTRODUCTION

Hydrogeology is the field that studies the origin, formation conditions, composition, and movement patterns of groundwater. Hydrogeological data is collected based on various measurements, analyses, and observations. Processing, analyzing, and presenting this data correctly is highly complex, and in this process, intellectual processing technologies are of significant importance.
Intellectual analysis of hydrogeological data is the process of studying important information regarding the condition, distribution, and management of groundwater. Through this analysis, it is possible to determine the availability and quality of water resources, as well as develop measures for water use and conservation. Intellectual analysis, especially through artificial intelligence and machine learning methods, plays a crucial role in efficiently processing data.
Intellectual processing of hydrogeological data helps in analyzing and obtaining high-quality results. This process involves not only the formation of data sets but also includes precise and efficient analyses. Intellectual processing of hydrogeological data, that is, the application of artificial intelligence and advanced analytical methods, is crucial and of significant importance. Today, hydrogeological systems and the management of groundwater resources have become important ecological and economic issues. The amount and complexity of data collected in these processes are increasing, which is why traditional methods of analyzing and managing them are no longer sufficient. From this perspective, the relevance of intellectual processing of hydrogeological data can be expressed in the following issues [Smith and Johnson, 2015; Fisher and Williams 2018]:
1. The large volume and complexity of the data. Hydrogeological data is often in very large volumes and complex, which makes it difficult to analyze effectively. In many cases, data is collected from various sources and comes in different formats, which complicates the integration process.
2. Uncertainty and errors. Hydrogeological data may contain errors or uncertainties. These errors can arise due to inaccuracies in measurement methods or mistakes during data collection. These uncertainties, especially, can cause issues during intellectual analysis.

3. The complexity of the data cleaning and preparation process. Hydrogeological data may be obtained from various sources, and there is a high likelihood of inconsistencies between them. The process of cleaning and preparing data for analysis requires a significant amount of time and resources.
4. Considering anthropogenic factors. Determining and analyzing the impact of anthropogenic factors on changes in the chemical composition of groundwater is very challenging. There may be uncertainties in identifying these factors, as their impact varies across different regions, and many factors need to be monitored when accounting for them.
5. Visualization and presentation of results. It is essential to present the results of hydrogeological analysis in an effective and understandable manner. This is especially important for specialists involved in decision-making. Proper visualization of results ensures that the data is easily comprehended.

To solve these problems, methods of intellectual analysis of hydrogeological data, along with data visualization techniques, should be employed.

Hydrogeological data consists of information on various characteristics of groundwater, including groundwater levels, chemical and physical properties of water, permeability coefficient, water pressure, and others. Each of these is of great significance based on the collected data.

Currently, as a result of previously conducted hydrogeological studies in the territory of the Republic, a large amount of factual material has been collected on the chemical composition of groundwater. This data is being updated with new information based on hydrogeological studies conducted annually [Dadajonova at al., 2024].

The main task of processing the chemical data of groundwater is, on the one hand, to study the general patterns in the formation of the chemical composition of groundwater and predict its changes under the influence of anthropogenic factors, and on the other hand, to introduce new methods in their processing [Rushton, 2004; Alekseeva at al., 2013].

In recent years, scientific and practical work has been carried out in the republic on the rapid determination of hydrogeological parameters of groundwater. This involves processing data and using modern monitoring technologies to identify groundwater components [Khabibullaev at al., 2021; Mardiev, 2021].

Hydrogeological data is crucial for the effective management and conservation of water resources. By intellectually analyzing the data, studying and evaluating it in depth, improving the distribution of resources, and using new technologies such as artificial intelligence, hydrogeological research can be carried out more effectively.

MATERIALS AND METHODS

The success of intellectual processing of hydrogeological data depends on modern technologies and methods. The data collected in this field is often large in volume, requiring the use of advanced approaches and methods for analysis [Basso and Fenicia, 2014; Blenkinsop, 2012]. Here is the structure of the main methods used in the process of intellectual processing of hydrogeological data (Figure 1).

The effective methods of intellectual processing of hydrogeological data can be classified as follows:

a) Data collection and aggregation.

Geophysical measurements. Various geophysical methods for studying the condition of underground water help to determine the location and characteristics of water sources through seismic and gravity measurements.

Sensors and automatic monitoring systems. Sensors and monitoring systems are used to monitor water levels, temperature, mineralization, and other physicochemical changes in real time.

b) Data analysis and modeling.

Statistical analysis. In order to study the characteristics of hydrogeological systems, methods such as statistical techniques, regression, correlation, and variance analysis are used to identify relationships and significant factors between the data.

Artificial neural networks. Artificial neural networks are used to model the complex changes of hydrogeological systems. This method allows for linking data with each other and evaluating changes.
Forecasting models. Differential equations, mathematical, and geostatistical models are used to forecast the future changes of hydrogeological systems.

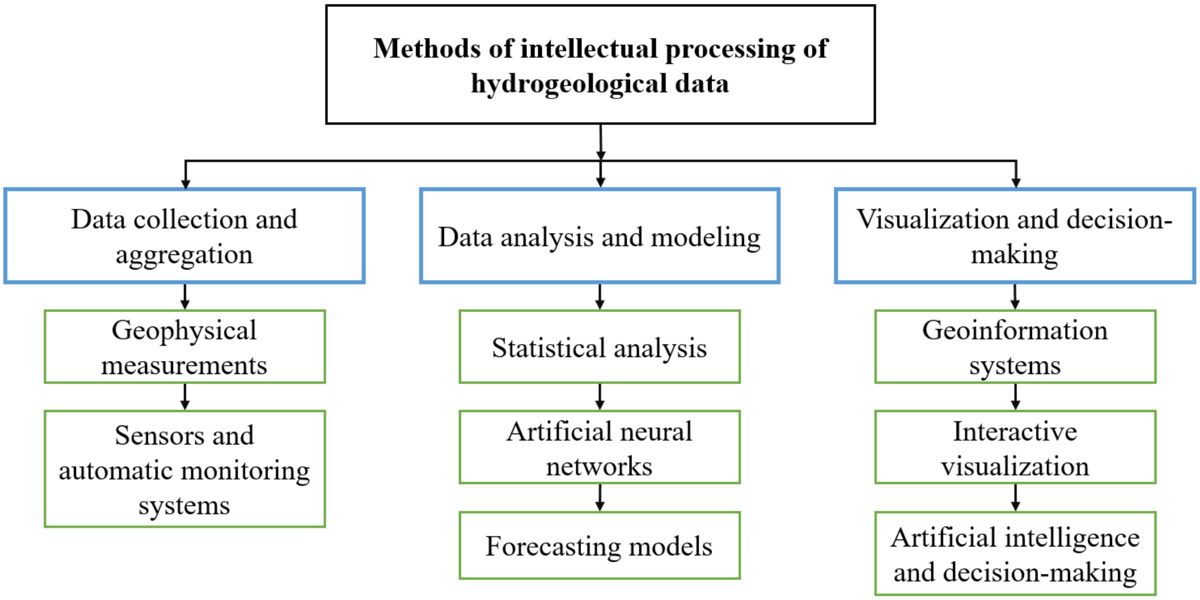

Figure 1. Methods of intellectual processing of hydrogeological data.

c) Visualization and decision-making.
Geographic information systems (GIS). With the help of GIS, hydrogeological data can be visualized, showing the location of groundwater sources, changes in their levels, and other parameters in the form of maps.
Interactive visualization. Through data visualization, users are provided with the opportunity to view and analyze changes in real-time. Interactive graphs, 3D models, and maps assist users in understanding hydrogeological processes.
Artificial intelligence and decision-making. With the help of artificial intelligence systems, it is possible to make accurate and efficient decisions based on the analyzed data. These decisions are crucial in managing hydrogeological systems and ensuring the efficient use of groundwater resources.
Methods of intelligent processing of hydrogeological data provide effective approaches for analyzing and managing data in the field of hydrogeology. The collection of data and the use of advanced technologies help create opportunities for assessing, monitoring, and managing hydrogeological systems [Van and Zander, 2019].
Various parameters are taken into account when performing the intellectual analysis of groundwater. These parameters are crucial for determining the condition of groundwater, managing it, and creating forecasts. The main parameters used in performing the intellectual analysis of groundwater are listed below:

- ✓ level;
- ✓ temperature;
- ✓ quality;
- ✓ pollution;
- ✓ flow rate;
- ✓ volume;

- ✓ chemical composition;
- ✓ anthropogenic impacts;

The intellectual analysis of groundwater is carried out based on a range of parameters. These parameters, in turn, are crucial for ensuring the effective management of hydrogeological systems, preserving water resources, reducing pollution risks, and improving the environmental condition.

RESULTS AND DISCUSSION

Through the intellectual processing of hydrogeological data, the condition, distribution, and changes of groundwater can be effectively analyzed, managed, and forecasted. By applying artificial intelligence, statistical analysis, and other advanced methods, hydrogeological systems can be understood more accurately and efficiently, enabling better resource management, reduction of environmental risks, and achieving socio-economic benefits [Rojas and Vasquez, 2020].

With the help of intellectual processing technologies, a more accurate and comprehensive understanding of the quantity, quality, and movement of groundwater can be achieved [Sahoo and Salas, 2021]. This, in turn, enables a better understanding and management of the condition of hydrogeological systems. Through the intellectual processing of hydrogeological data, the following results can be achieved:

- *The distribution and quantity of groundwater are clearly depicted.*
- *Detailed information is obtained about the changes in water quality and composition (such as pollution levels, chemical composition, and others).*
- *The necessary data for the distribution of water resources and their effective management is provided.*

The use of artificial intelligence and machine learning technologies for modeling hydrogeological systems helps create more accurate and complex models by taking into account various factors of the system [Simoni and Bogaard, 2020]. The following results are obtained from these models:

- *Accurate forecasts and predictions about the movement and distribution of water.*
- *Simulation of the movement of geological layers and water through different strata.*
- *Monitoring the system's status in real-time and providing quick responses to changes.*

Through intellectual processing, the following results can be achieved for the effective management of hydrogeological systems:

- *The use of water sources is properly managed, ensuring that resources are correctly allocated to meet the demands of irrigation, industry, and drinking water.*
- *Advanced forecasts enable the implementation of proactive measures to prevent frequent occurrences of water shortages and droughts.*
- *Effective strategies for the restoration of used water from natural sources are developed.*

The main results of analyzing and preventing environmental risks in hydrogeological systems are as follows:

- *Identification of polluted water sources and management of their restoration processes.*
- *The quality of groundwater and its impact on health are analyzed, which helps reduce various ecological and economic risks.*
- *Environmental risks are forecasted, and future changes are identified in advance, allowing for preventive measures against potential hazardous situations.*

Decisions made in the management of hydrogeological systems are often based on the accurate and comprehensive analysis of data. Intellectual processing provides the following results:

- *The decision-making process is based on the completeness and accuracy of the data, which leads to more effective and optimal solutions.*
- *The ability to monitor the status of water resources in real-time is created, which facilitates the quick decision-making process.*

The implementation of new technologies and innovations in the management of hydrogeological systems brings the systems to a more efficient and advanced level. These include the following:

- *Automated systems are developed for monitoring and analyzing water resources in real-time.*
- *Accurate depiction of the movement and distribution of groundwater through 3D modeling.*
- *IoT technologies and sensors are used to monitor the status of water sources in real-time and for effective management.*

The results of intellectual processing of hydrogeological data bring significant changes in important areas such as improving the efficiency of groundwater management, reducing environmental risks, conserving water resources, and adapting to climate change. This process is of significant importance not only from a scientific perspective but also practically, as it enables the sustainable management of water resources and ensures environmental safety.

CONCLUSION

Intellectual analysis of hydrogeological data is a complex yet crucial process, and through artificial intelligence and machine learning methods, the analyzed data helps in developing new approaches in hydrogeology. Through intellectual analysis, it is possible to establish relationships between groundwater parameters, forecast changes, analyze data, and ensure the effective decision-making process. This, in turn, enables the adoption of complex decisions necessary for the effective management and conservation of water resources.

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