ARTICLE

ORGANIZATION AND APPLICATION OF INFORMATION AND ANALYTICAL SUPPORT FOR GEOLOGICAL MONITORING OF WATER USE

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ABSTRACT

The article presents an approach to organizing geoecological monitoring of water by the creation and application of an information-analytical system that uses both and local operational observations, as well as modern GIS technologies. For the formation of a basic platform for the organization of a single information and analytical space, the processing of geoecological monitoring data at a local and regional level is considered. The structure of information and analytical support for the collection and processing of geoecological monitoring data has been developed. An algorithm has been developed for assessing the geoecological state of decentralized water supply. The algorithm is built on the basis of the interpolation model of the time series of the annual cycle, built on the basis of regime observations based on GIS data. A digital relief model of the investigated territory of the Navashino district is built. The paper presents the results of experimental studies. The site of the local observations was the territory of the Chud village (Nizhny Novgorod region). At the selected site, preliminary hydrogeological work was carried out with the determination of the conditions for the movement of karst waters and the zones of location of the main sources of decentralized water supply were determined.

KEY WORDS
information and analytical systems, GIS data, information processing services, assessment algorithm, digital model, water use.

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INTRODUCTION

Currently, water supply in an area remote from large settlements is based on the use of hydrological resources through decentralized water supply systems (springs, wells). The use of decentralized water supply in remote settlements is in many cases the only possible [1-5]. Based on the studies and a comprehensive analysis of the features of water use in such territories, it was found that the main problems of the water management complex are as follows:

- poor condition of objects of economic and drinking water supply;
- poor management of irrigated farming systems, usually used in areas of decentralized water supply;
- wasteful water use and negative anthropogenic impact on water bodies and consequently unsatisfactory water quality in water bodies;
- increasing vulnerability of water use systems from the harmful effects of natural and technogenic nature, especially in areas of active agro-industrial development of the territory. A high degree of impact on water bodies is exerted by dispersed (diffuse) runoff from agricultural and residential territories occupied by industrial waste;
- imperfection of legislative, regulatory, technological and information support [6,7].

On the territory of the Russian Federation, geo ecological monitoring systems of various levels have been developed and are functioning, within the framework of which regular monitoring of water supply to the population is carried out. However, the drawbacks of the monitoring systems currently used are that systematic monitoring of water use and water quality is carried out only with centralized water supply [8]. Monitoring of decentralized water supply, unscheduled inspections aimed at preventing harmful effects on the health of the population of poor-quality drinking water, reveal only a part of violations and inconsistencies. Extremely few published data on the quality of water used for drinking needs extracted from private wells and boreholes located in local areas. They, as a rule, are not included in monitoring programs, and the control functions at the moment are actually assigned to users.

Solving the indicated problems requires more effective approaches to organizing geo ecological monitoring of water use through the creation and application of modern information and analytical systems using both locative and local operational observation data and modern GIS technologies.

The structure of the information-analytical support of the geo ecological monitoring

The use of information-analytical systems should be aimed at providing the following basic principles of the water management for achieve the purpose and solve of tasks [9]:

- the principle of the management of the water use, that aimed at the preserving and the restoring of the functional and the structural integrity of catchment areas, landscapes and aquatic ecosystems;

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- the principle of the compliance of the environmental priority of the protection of water bodies, as well as water management activities must meet environmental requirements and restrictions and water management activities must not have the negative influence on the environment;
- the principle of the priority of the use of water bodies for purposes of the drinking and household-domestic water supply over other purposes of their use. It is subject to the compliance of the balance of the use, of the reproduction and of the protection of waters from pollution and depletion.
- The basis for the construction of systems of the geo-ecological monitoring is technical and information means, which are combined on the basis of the systematic approach to solve the following tasks:
- the organization of regular observations for the condition of the hydrogeological environment based on quantitative and qualitative indicators;
- the organization of the collection, of the processing and of the analysis of data of the water use, that obtained as the result of observations at locative and local levels;
- assessment and forecasting of changes in the state of researched water bodies, the development of management actions based on the obtained information of locative and local levels and GIS data [10].

Monitoring levels are distinguished by the scale of observations. The initial level is the locative level of the geo-ecological monitoring. It covers territories of small villages, towns, individual enterprises, factories, economic complexes, etc. Locative levels are integrated into the larger network (within the limits of district or city). This integrate forms the system of the local level of the geo-ecological monitoring. Systems of the local level are combined into larger ones - regional monitoring systems, which cover territory of the region or the limits of several regions. The regional geological monitoring is designed to assess changes in the geological environment in territories of the complex anthropogenic influence. Such monitoring solves tasks of the estimate of the influence on the geological environment at the project stage and it does not provide for the creation of a new special network of regime observations [11].

The information processing of data is built on the locative and local levels in the system of geo-ecological monitoring. The locative and local monitoring is determined by the specific conditions of the execution of the geo-ecological monitoring and by features of specific objects of the hydrogeological environment [12, 13]. Upper horizons of the lithosphere and main objects of water use are as the object of the research in the geo ecological monitoring of the decentralized water use. Upper horizons of the lithosphere research in limits of the hydrogeological environment [14]. The [Fig. 1] shows the generalized scheme of the information processing of geo ecological monitoring data.

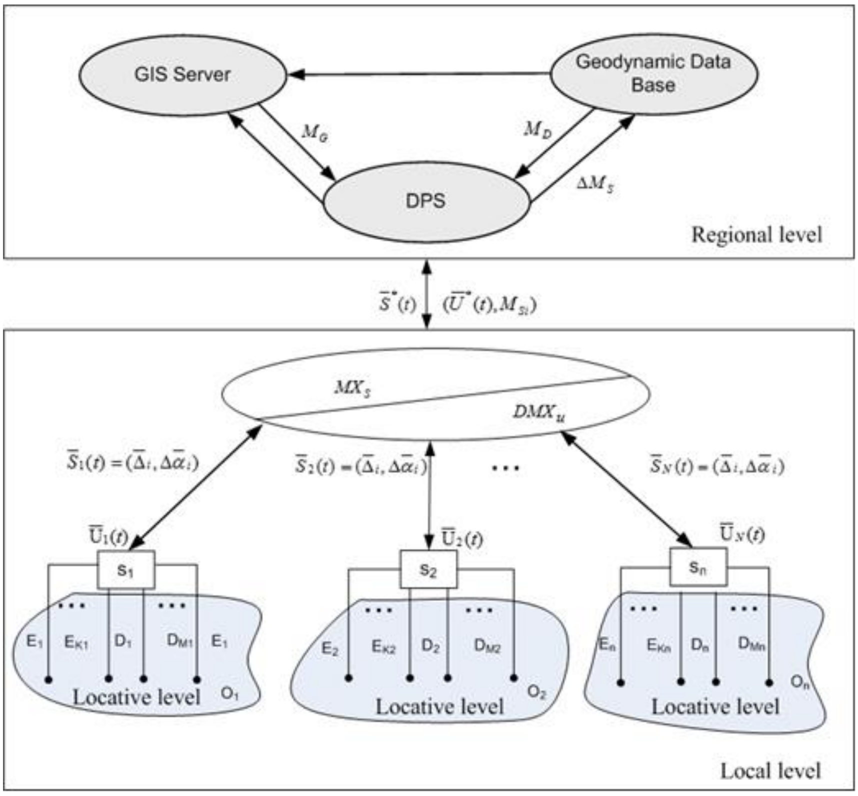

Fig. 1: The generalized scheme of the information processing of geo ecological monitoring data.

In the presented figure, hierarchical levels of data processing of the geo ecological monitoring of the decentralized water use are highlighted. At the same time, the level of locative observations was highlighted, which provides the initial operational information for the analysis, and which combined at the local level of hydrogeological monitoring. The next level execute the collection and management of the geo-ecological monitoring system at the level of the interaction with the regional geographic information system (GIS) with the allocation of the hydro-geodynamic vector of model data mismatch with real observation data.

The data server of the local level is used for combine of the data of the information-measuring complexes of locative levels and it is used for formation of the base platform for the organization of the single information - analytical space. This server is designed to collect observation data from information-measuring systems, which located in the area of its service. The size of the service area is selected in accordance with the number of information-measuring complexes and systems up to 100 square km., parameters of communication channels between measuring complexes and the regional server, the number of user queries to existing databases. All parameters (metrological characteristics of measuring complexes, parameters at which measurements were taken, spatial coordinates of the object under research, characteristics of the surrounding area) are transmitted by measuring complexes and systems to the central server along with primary digital data. It is for systematize primary data and into account parameters of the collection of data [15]. Reducing of the fragmentation of existing measuring complexes should be achieved through the software of the local data server. In particular it is by providing specialized services of the processing information.

In accordance with the considered principles of the information processing, the structure of the information-analytical support of the collection and of the processing of the geo-ecological monitoring data can be represented in the generalized modular form [Fig. 2].

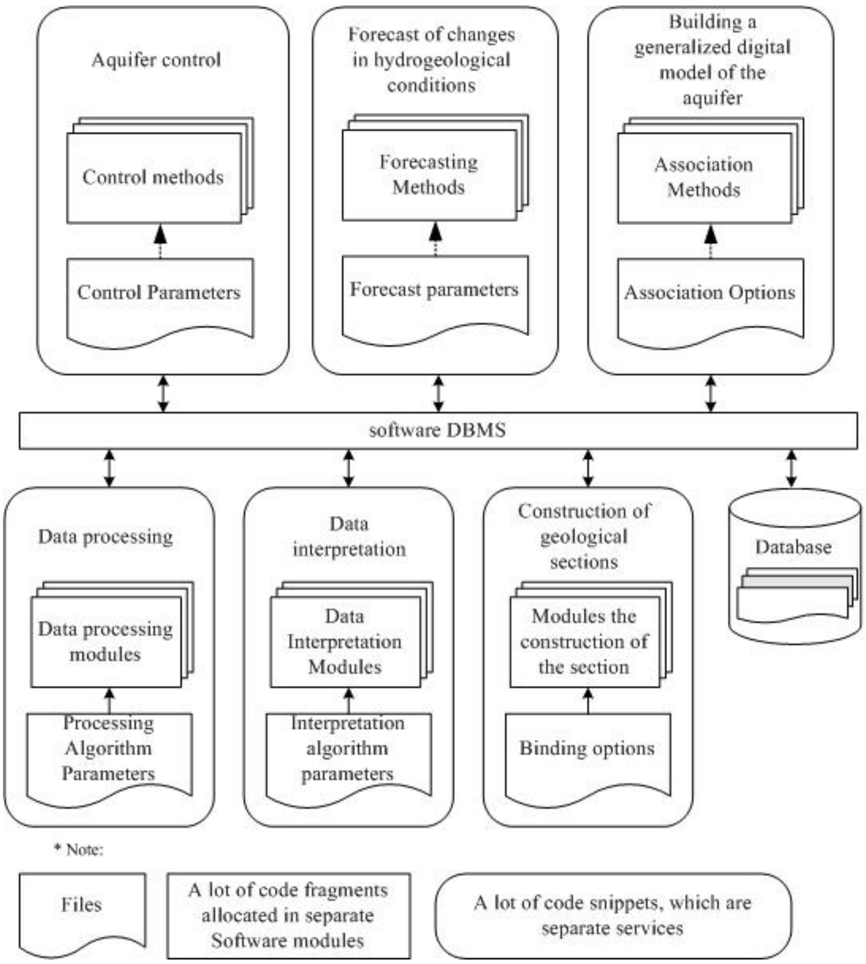

Fig. 2: The generalized modular form of the information-analytical support.

[Fig. 2] shows, that the local data server provides services of data processing and of the interpretation of data. In addition, the processing algorithms of each service are divided into separate modules. It is very convenient when adding new ones, as well as correcting old processing methods and algorithms. The presence of a large amount of source and of processed data and the ability of adding of new methods of the processing and of the interpreting data, provide the user the simple way of the compare and of the analyze these methods and algorithms, and it is give the flexible and fast mechanism for testing new methods [16].

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MATERIALS AND METHODS

Algorithms of assessing of the geo-ecological state of the decentralized water supply

The assessment of the local level of the geo-ecological state of the decentralized water supply can be carried out on the basis of the joint spatio-temporal processing of observation data of the locative level and the initial information from GIS databases. In this case, the geodynamic parameter is the parameter of the control. This parameter is the depth of locate of the aquifer for the decentralized water supply in the i of control zone. Second parameter is the integral parameter of water quality - water salinity are taken. It is taken after temperature correction as the result of the preliminary processing of geo-electric data of the locative control.

The processing algorithm is built on the basis of the interpolation model of time series of the year cycle, which is built on the basis of operational observations by GIS data. For each locative observation zone, model forecast series of aquifer parameters are formed by upcoming year cycles:

$$h_i = a_{0i} + a_{1i} \cdot t + a_{2i} \cdot t^2 + \ldots + a_{ni} \cdot t^n$$
$$m_i = b_{0i} + b_{1i} \cdot t + b_{2i} \cdot t^2 + \ldots + b_{ki} \cdot t^k \ , \qquad (1)$$

where и - coefficients of the forecasting model; and - the level of the model.
Abnormal changes of the recorded data are determined at locative levels according to the following boundary conditions

$$\frac{\partial^{[n+1]} h_i}{\partial t^{[n+1]}} \geq \varepsilon_{hi} \text{ or } \frac{\partial^{[k+1]} m_i}{\partial t^{[k+1]}} \geq \varepsilon_{mi} \ , \qquad (2)$$

where ε_{hi} , ε_{mi} - forecast thresholds of the assessing of the limit of aquifer parameters at locative levels
The generalized model of the geo-ecological state of decentralized water supply of the local level is formed on the basis of the following relationships:

$$\mathrm{E}_h = \int_S \gamma_{hi} \left| \frac{\partial^{[n+1]} h_i}{\partial t^{[n+1]}} \right| \partial S \leq \max\{\mathrm{E}_h\}$$
$$\mathrm{E}_m = \int_S \gamma_{mi} \left| \frac{\partial^{[k+1]} h_i}{\partial t^{[k+1]}} \right| \partial S \leq \max\{\mathrm{E}_m\} \ , \qquad (3)$$

where γ_{mi} , γ_{hi} - weighting factors, which taking into account the rating of information at locative observation points; - the zone of the local monitoring of the geo-ecological state of the decentralized water supply; $\max\{\mathrm{E}_h\}$, $\max\{\mathrm{E}_m\}$ - maximum deviation thresholds of generalized estimates.

Weighting coefficients are determined in accordance with the rating information coefficients k_i of locative observation points, which are formed on the basis of hydrogeological data of GIS.

$$\gamma_{hi} = \frac{k_i \dfrac{\max\{\Delta h_i\}}{a_{0i}}}{\sum_{i=1}^{N} k_i \dfrac{\max\{\Delta h_i\}}{a_{0i}}} \ ,$$
$$\gamma_{mi} = \frac{k_i \dfrac{\max\{\Delta m_i\}}{b_{0i}}}{\sum_{i=1}^{N} k_i \dfrac{\max\{\Delta m_i\}}{b_{0i}}} \ , \qquad (4)$$

where - the total number of locative control points in the system of the automated monitoring of the geo-ecological state of the decentralized water supply at the local level, $\max\{\Delta h_i\}$, $\max\{\Delta m_i\}$ - maximum forecast deviations of aquifer parameters at locative observation points.

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Description of the study area

The territory on which geo ecological studies were carried out is located in the north-eastern part of the Navashinsky district and includes 19 settlements. The total area of the settlement is 267.13 square kilometers. A significant part of the territory of the settlement is subject to karst formations, this is confirmed by the presence of craters, basins and lakes of karst origin. The territory belongs to the western part of the Volga Upland and is a hilly-plain relief between the rivers Oka and Tesha. Geologically, the settlement area belongs to the upper part of the Perm system, the lower sub-tier of the Kazan tier. Deposits are represented by dolomites, limestones, marls and clays. In the southwestern part of the Settlement, rivers flow along weakly cut flat-bottom valleys and have wide floodplains. The relief is mostly flat, areas with a slope of less than 1 degree make up about 90% of the settlement. The hydrographic network of the territory in question is represented by the Oka River, the Teshey River, small sections of the Led and Bolshaya Kutra rivers, as well as numerous lakes and streams. By the nature of the water regime, the rivers belong to the East European type with distinct spring floods, stable summer low water, interrupted by small rain floods and a stable low winter low water. The main role in their nutrition is played by precipitation, groundwater provides a steady low-water flow. Spring level rise begins in late March - early April, even during freezing and lasts 15-20 days. During the flood period, the water level regime of the Tesha and Bolshaya Kutra rivers is dependent on the Oka River. The decline in spring flood levels is slow and lasts about a month. The winter regime begins at the end of November, when the rivers are covered with ice. Water consumption during this period is sharply reduced, and on small streams stops altogether.

The Tesha River, the right inflow of the Oka River, originates on the Volga Upland, has a length of 311 km, a basin area of 7800 square kilometers. The river has 9 large inflow. In the territory under consideration, the river flows in its lower course, partly along the floodplain of the Oka River. The largest old lake in the settlement are located in the floodplain of the river. Oka: Stary Klyuch -1 03.4 hectares, Kharitonovo - 61.1 hectares, Glubokoe - 13.0 hectares, Ivanovo - 11.6 hectares, Mordovo - 8.7 hectares, Sitnoye - 5.6 hectares, Dolgovsky - 4.8 hectares, Dalnee - 3,3 hectares. Lakes of karst origin, which are natural monuments - Big Svyatoye Dedovo, Small Svyatoye. Big Svyatoye Dedovo Lake has an area of 128.1 hectares, a depth of up to 20m. In the territories of settlements and in their vicinity there are a large number of ponds organized on watercourses.

For observation, a site was selected on the second floodplain terrace of the Teshi River, which flows 3.5 km south of Lake Svyato. Water samples from different aquifers were taken on the coastal territory of the lake and in the vicinity westward towards the Oka River, a chemical analysis of the main water indicators determining the presence and development of karst processes was carried out. In hydrogeological terms, the area is characterized by the presence of two aquifers. The first horizon refers to the Quaternary and alluvial sands, the second to the fractured and destroyed rocks of the Kazan and Sakmara tiers. The Quaternary alluvial deposits of the second floodplain terrace of the Teshi River pass on the research site. In the upper part of the layer, the sands are fine-grained, with depth turn into different-grained [17,18]. Figure 3 presents a digital elevation model of the study area of the Navashinsky district. The model was built using the Arc GIS package (Arc Map10.4.1) using satellite imagery from the Landsat 8 satellite with an accuracy of 10-15 meters in the WGS - 84 coordinate system.

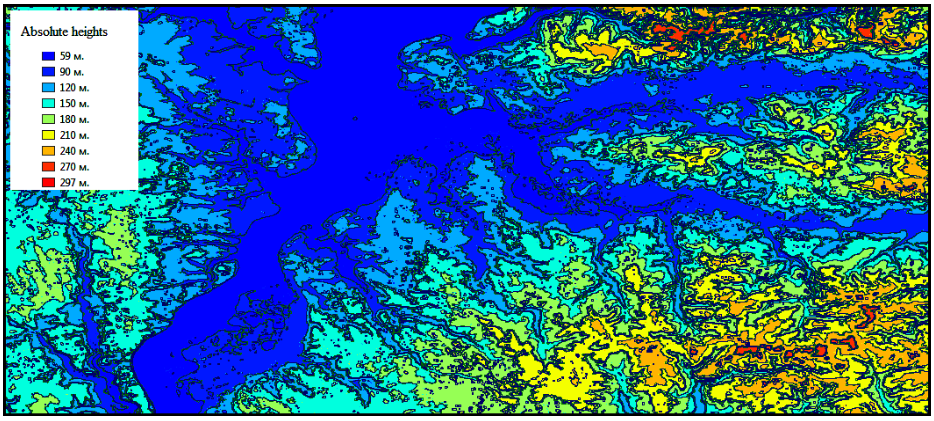

Fig. 3: Digital elevation model of the study area.

The relief of the territory as a whole is flat with alternating low-lying plains and hills with fluctuations in absolute elevations of 100-300 meters

RESULTS & CONCLUSION

The site of the local observations was the territory of the village of Chud, Nizhny Novgorod region. The purpose of the experimental work and the organization of regime observations on the territory of decentralized water supply is to test the developed system of dynamic hydrogeological control with

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information and analytical support. Hydrogeological control is based on the allocation of key geodynamic zones and the use of geoelectric methods [19,20]. At the selected site, preliminary hydrogeological work was carried out with the determination of the conditions for the movement of karst waters and the zones of location of the main sources of decentralized water supply were determined. Based on the preliminary work, the key points of hydrogeological control of the territory were identified. The karst massif is divided into the region of infiltration and inflation of atmospheric precipitation and surface water, the region of underground runoff, and the area of discharge or discharge of karst waters beyond the boundaries of karst rocks. Regime observations were carried out from February to September 2017 at eight points of local control using a bipolar equipotential unit. [Fig. 4] shows the data of mineralization registration at the hydrogeological control point.

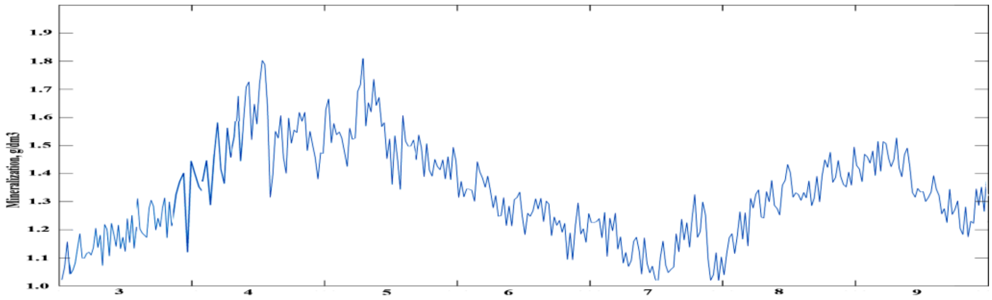

Fig. 4: Mineralization data of water used for drinking water supply in the village of Chud.

Based on the studies, it was noted that with the development of karst-suffusion processes, the intensity of hydrogeological variations of local sections of the geological environment in the study area has a pronounced dynamically unstable character. In accordance with the data obtained, zones of safe drinking water use are identified, as well as a zone with a disturbed hydrogeological regime and undesirable use of water for drinking water supply. Based on the studies, it can be concluded that in settlements in such a territory it is necessary to carry out work using the developed hydro geodynamic control system with a period of at least 5 years (the recommended period of astrological monitoring), and in the case of activation of surface manifestations of karst processes in the territory more often.

CONFLICT OF INTEREST

There is no conflict of interest.

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