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STUDY OF THE STATE OF NATURAL-ANTHROPOGENIC GEOSYSTEMS UNDER CONDITIONS OF LIMITED FUNCTIONING OF THE UNDERGROUND HYDROSPHERE MONITORING SYSTEM

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INTRODUCTION

The modern stage of development of cities, which include large industrial and ecologically dangerous complexes, requires an objective assessment of the state and forecast of possible changes in the geological environment. As a result, of long-term ignoring of interdependent issues of hydrogeological and ecological substantiation of economic and construction activities in modern megacities, today we have huge economic losses and risks of manifestation of dangerous processes. Compliance with the conditions of ecological and man-made security of the territory is impossible without taking into account the peculiarities of its geological structure. The stability and dynamism of urbanized natural and man-made geosystems as a whole is determined by a number of factors, among which the state of the underground hydrosphere is important. Therefore, the assessment of the state of the geological environment and the risk of dangerous natural and man-made phenomena or processes is one of the urgent practical tasks.

Assessment of the existing natural and man-made situation and forecast of changes requires a detailed hydrogeological study of the territories. With modern construction, reconstruction of old buildings, intensive development of the underground space, the man-made load on the geological environment increases many times, first of all, the hydrogeological conditions of the territory are radically changed. The existing underground water regime is violated, which often leads to the emergence or activation of negative engineering and geological processes and even emergency situations[1]. It can be argued that the state of natural-anthropogenic geosystems as a whole is determined by a number of factors, among which the priority is the state of groundwater. This requires the creation and functioning of the underground hydrosphere monitoring system, which involves the use of modeling methods.

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[1] Водообмен в гидрогеологических структурах Украины. Водообмен в нарушенных условиях / В. М. Шестопалов, Н. С. Огняник, Н. И. Дробноход и др. Київ : Наук. думка, 1991. 528 с.

1. Changes in the geological environment and hydrogeological conditions of technogenically loaded territories on the example of the territory of the city of Kyiv

As a result, of the intensification of urbanization processes, the formation of agglomerations and the increase in the area of cities, the anthropogenic load on the territory has increased tremendously. As a result, there are changes in the balance of underground water and the location of the groundwater surface. Fluctuations in the groundwater surface cause a change in the properties of rocks in the upper part of the lithosphere (mostly, their stability decreases); geodynamic conditions (geological processes are activated or arise); hydrogeological conditions, namely the relationship between soil and interlayer aquifers. The quality of groundwater deteriorates, seepage, suffusion and karst processes are activated, the aggressiveness of water to concrete increases, the soil in the aeration zone becomes salinized; engineering and seismological conditions are changing. There is also a deterioration in the conditions of industrial activity and people's residence (the sanitary-epidemiological condition is deteriorating). Usually, hydrodynamic changes under the influence of urbanization consist, first of all, in a decrease in the depth of groundwater and an increase in the strength of its horizon.

Urban development activities fundamentally changed the natural geological environment and hydrogeological conditions of the territory of the city of Kyiv. As a result, of human activity, man-made landforms and a thick layer of man-made deposits have been formed. Significant anthropogenic influence has led to changes in the channel regime of small rivers (their channels are channelized, the feeding area is under continuous construction), which, due to their large number, are one of the important geomorphological elements of the city of Kyiv. However, the hydrodynamic conditions and geofiltration processes in the floodplains of small rivers and their adjacent territories have been little studied from the point of view of the formation of groundwater levels in the city. The study of changes in hydrodynamic conditions requires the creation of a monitoring system taking into account the need for complex observations of groundwater, changes in engineering and geological conditions, seismicity, and the development of exogenous geological processes. At the same time, during the organization and conducting of observations, the factors that cause the manifestation and activation of negative processes should be taken into account, first of all. There is no monitoring system in Kyiv that would meet such requirements.

The most effective method of studying and forecasting the dynamics of groundwater levels is mathematical modeling of geofiltration. The construction of mathematical models of groundwater flows in general and especially for areas subject to significant anthropogenic stress is one of the important tasks of modern hydrogeological research. However, in order to create such models in order to establish regularities of changes in groundwater levels in the territory of Kyiv city, it is necessary to analyze a large volume of raw data of various topics and create a set of resulting materials of an evaluative nature. For the territory of the city, the task is significantly complicated by the lack of a monitoring system, the incompleteness, inaccuracy and unsystematic nature of the available hydrogeological and hydrological information, as well as the difficulty of conducting new large-scale hydrogeological studies (1:10,000 and larger)[2]. In addition, densely built-up areas of the territory are characterized by uncertainty of data on losses from water-bearing communications, as well as disruption of the natural hydrogeological situation due to construction, repairs, changes in the regime of surface runoff and vertical moisture transfer. Therefore, it is advisable to solve the problem of preservation, generalization, accumulation and analysis of existing heterogeneous and spatially unorganized hydrogeological information using modern geoinformation technologies (GIS technologies). The use of spatial analysis tools and the integration of GIS with systems of mathematical modeling of geofiltration significantly expand the possibilities of studying the dynamics of groundwater levels in the territory of Kyiv city[3].

It should be noted, that nowadays the processes of intensive anthropogenic transformation of the environment continue – territories that were considered difficult to access until now due to the fragmented terrain and high level of groundwater are being developed, therefore hydrogeological studies are relevant. Among the main tasks of such research, two can be singled out.

1. Study of spatio-temporal patterns of groundwater formation, which can be studied on the basis of a monitoring or stationary reference observation network. Spatio-temporal observation data are necessary for forecasting the natural or disturbed regime of groundwater, as well as their mapping. In addition, these data should provide initial information for the construction of maps of hydrogeological parameters and predictive mathematical models.

2. Assessment of anthropogenic impact on groundwater in order to forecast possible changes in hydrogeological conditions and timely application of protection measures and development of recommendations for the rational use of groundwater and its impact on the state of the geological

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[2] Koshliakov, O., Dyniak, O., Koshliakova, I. Modeling in monitoring system of underground hydrosphere for territories under technogenic pressure. Abstract of XIII International Scientific Conference on Monitoring of Geological Processes and Ecological Condition of the Environment, Kyiv, 2019, Ukraine. DOI: https://doi.org/10.3997/2214-4609.201903232

[3] Koshliakov, O., Dyniak, O., Koshliakova, I. Providing the information component of hydrogeological processes using GIS in Kiev. Abstract of 14-th International Conference Geoinformatics. *Theoretical and Applied Aspects*. Kyiv, 2015, Ukraine. DOI: https://doi.org/10.3997/2214-4609.201412407

environment. The water management influence most intensively changes the hydrogeological conditions, water and salt balance of groundwater and requires detailed studies that will provide the necessary information for forecasting the regime of groundwater.

It is obvious that the network of hydrogeological monitoring of the city territory should be focused on the study of both natural and disturbed groundwater regimes and should be included in the overall environmental monitoring system.

2. Peculiarities of monitoring the state of the underground hydrosphere of technogenically loaded territories

In general, the environmental monitoring system (in which the underground hydrosphere monitoring system is one of the components) is a system of observation, collection, processing, transmission, preservation and analysis of information about the state of the environment, forecasting its changes and developing scientifically based recommendations for making decisions about the prevention of negative changes in the state of the environment and compliance with environmental safety requirements. This is an open information system, the priorities of which are the protection of the vital ecological interests of man and society; preservation of natural ecosystems; averting crisis changes in the ecological state of the environment and preventing emergency environmental situations.

The creation and functioning of the monitoring system for the purpose of integration of environmental information systems covering certain territories should be based on the following principles:

– coherence of normative and legal and organizational and methodological support;

– compatibility of technical, information and software of its constituent parts;

– systematic observations of the state of the environment and man-made objects affecting it;

– timeliness of obtaining, comprehensiveness of processing and use of environmental information received and stored in the monitoring system;

– the objectivity of primary, analytical and predictive environmental information and the efficiency of its delivery to state authorities, local self-government bodies, public organizations, mass media, the population of Ukraine, interested international institutions and the world community.

Environmental monitoring is carried out by relevant state institutions, their bodies on the ground, as well as enterprises, institutions and organizations belonging to the sphere of their management, which are subjects of the monitoring system under national and regional (local) programs for the implementation of relevant environmental protection measures.

The monitoring system is aimed at:

– increasing the level of study and knowledge about the ecological state of the environment;

– increasing the efficiency and quality of information service for users at all levels;

– improving the quality of justification of nature protection measures and the effectiveness of their implementation;

– promoting the development of international cooperation in the field of environmental protection, rational use of natural resources and environmental safety.

The main tasks of the subjects of the monitoring system are:

– long-term systematic monitoring of the state of the environment;

– analysis of the ecological state of the environment and forecasting its changes;

– information and analytical support for decision-making in the field of environmental protection, rational use of natural resources and environmental safety;

– information service of state authorities, local self-government bodies, as well as provision of environmental information of the country's population and international organizations.

Subjects of the monitoring system ensure the improvement of the environmental monitoring networks subordinated to them, the unification of observation methods and laboratory analyses, devices and control systems, the creation of data banks for their multi-purpose collective use with the help of a single computer network that ensures the autonomous and joint functioning of the components of this system and the relationship with other information systems operating in Ukraine and abroad.

The monitoring system should be based on the use of the existing organizational structures of the monitoring subjects and functions on the basis of a single regulatory, organizational, methodological and metrological support, unification of constituent parts and unified components of this system.

Metrological support for the unification of constituent parts and components of the monitoring system is carried out on the basis of:

– unified scientific and technical policy regarding standardization, metrology and certification of measuring, computer and communication equipment;

– a single regulatory and methodological base that ensures the reliability and comparability of measurements and results of environmental information processing in all components of this system.

Subjects of the monitoring system, local state administrations and local self-government bodies, enterprises, institutions and organizations, regardless of their subordination and forms of ownership, must carry out:

– development and coordination with relevant state bodies of plans for the implementation of measures aimed at monitoring the state of environmentally hazardous objects, preventing environmentally hazardous industrial, economic and other activities.

– protection of observation posts (points, stations) registered in the monitoring system of environmental objects from damage and unauthorized transfer;

– allocation of land plots in accordance with the established procedure for setting up new observation posts on the basis of approved improvement and development programs of the components of the monitoring system.

The relations between the subjects of the monitoring system are based on:

– mutual informational support of decisions in the field of environmental protection, rational use of natural resources and environmental safety;

– coordination of actions during the planning, organization and implementation of joint events for ecological monitoring of the environment, occurrence of emergency environmental situations and liquidation of their consequences;

– effective use of existing organizational structures, means of monitoring environmental objects and computerization of activity processes;

– contributing to the most effective solution of joint tasks of environmental monitoring and environmental safety;

– responsibility for the completeness, timeliness and reliability of the transmitted information;

– collective use of information resources and communication tools;

– free information exchange.

Changes in the geological environment in the process of urbanization, determination of the conditions and factors for the formation of groundwater in urbanized areas, require consideration of the peculiarities of creating a system and conducting monitoring in such areas.

The task of monitoring territories subject to fluctuations in groundwater levels, and those where this process can be real during a certain estimated time (the period of operation of structures, the existence of an object), necessitates the use of complex observations of groundwater, changes in engineering and geological conditions, seismic activity, development of exogenous geological processes[4]. At the same time, during the organization and conducting of observations, first of all, factors that cause the manifestation and activation of

[4] Кошляков, О., Диняк, О., Чомко, Д., Кошлякова, І. Врахування закономірностей формування, розподілу та впливу підземних вод з метою обґрунтування прогнозної гідрогеологічної моделі на ділянках ущільненої міської забудови. *Вісник Київського національного університету імені Тараса Шевченка. Геологія*. 4 (87), 2019. Р. 96–99. DOI: http://doi.org/10.17721/1728-2713.87.14

this process should be taken into account. In many cases, not only the limits of the development of negative phenomena and their changes in space and time depend on the type of factors, but also the justified choice of observation methods, the location of observation points, and the frequency and volume of measurements. But in all cases, the results of observations of certain indicators of the state of the geological environment should be of the same type and suitable for use for the purpose of forecasting at all levels, that is, the results of observations at the object level should also be suitable for use at the local, regional and state levels. This can be realized only with a systematic approach to organization and monitoring. In order for the monitoring to meet the mentioned requirements, it is necessary to carry out complex observations at all levels, which should include: measurement of water levels in the soil and interlayer aquifers adjacent to them, assessment of the aggressiveness of groundwater, study of changes in indicators of engineering and geological conditions and development exogenous geological processes.

During search operations, it is necessary to use exploratory wells as a temporary observation network. Wells should be placed in the form of rows oriented from watersheds to natural drains in such a way that all characteristic complexes of water-bearing rocks and geomorphological elements are covered by the observations. It is advisable to place the structures also in the direction of the maximum change in hydrogeological indicators. In areas with difficult geomorphological and lithological conditions, the observation network should be thickened. In areas where groundwater is fed by pressure water, it is advisable to install piezometers that are immersed to different depths.

Observations of the groundwater regime should be comprehensive, that is, include the study of changes in their level, temperature, and chemical composition. The frequency of observations should take into account the nature and degree of influence of natural and man-made factors. On average, it is necessary to monitor the underground water regime once every 6 months. In periods of intense influence of mode-forming factors, the frequency of monitoring the mode of underground water (especially soil) increases by 2–3 times.

In the conditions of anthropogenic (artificial, significantly disturbed) underground water regime, it is necessary to apply specific approaches and methods of monitoring the underground hydrosphere. In particular, the principles of placement of the observation network should ensure the study of the peculiarities of the disturbed regime and the quantitative assessment of the influence of man-made factors (leaks, water intake, drainage, irrigation) on individual elements of the regime.

As already mentioned, changes in engineering-geological and hydrogeological conditions as a result of fluctuations in groundwater levels occur at different levels: object, local, local, regional. At each level, when assessing changes in engineering-geological and hydrogeological conditions, it is necessary to take into account sources of additional groundwater supply. At the same time, it should be taken into account that monitoring has two main tasks: control of areas with high groundwater levels and detection of areas where this may occur. In this regard, the method of justifying the placement of observation points in the monitoring system should take into account the placement of sources and factors of natural and man-made disturbance of the groundwater regime.

The analysis of the existing observation systems at the object and local levels shows that, unfortunately, they mostly do not meet the modern requirements for monitoring the state of the underground hydrosphere, both in terms of complexity and technical support.

It should be added that the information obtained from existing stationary monitoring points is not always sufficient for a reliable analysis of specific situations. This is due to:

– inconsistency in the time of measurements at different points;

– mismatch of the list of monitored parameters;

– disproportionality of analytical capabilities of various departmental laboratories and their technical support;

– interest in hiding critical situations;

– insufficient or complete lack of financing of the environmental control system in individual organizations;

– non-compliance with standards or sampling methods.

All this increases the statistical dispersion of the received information and reduces its reliability, which complicates the use of data for the purpose of establishing the factors of formation of the groundwater regime.

Usually, a series of hydroisogypsum maps for different periods of time are compiled to determine the factors of formation and to identify patterns of groundwater dynamics based on monitoring or regime observations. The accuracy of such maps directly depends on the density of observation points. Within the city of Kyiv, the regime network reached its maximum development in 1986, after which the number of network points decreased all the time. It can be stated that today the regime network in Kyiv is in a critical state.

Unfortunately, Kyiv does not have a single centralized groundwater monitoring system, the main task of which would be to quickly assess the current state and forecast its changes in order to prevent negative (sometimes catastrophic) ecological and geological phenomena and processes in a timely manner. The functioning of such a system would make it possible to significantly improve ecologically based planning of the development and reconstruction of the city's territory and its engineering infrastructure, and to significantly reduce costs for the prevention or elimination of negative ecological and geological phenomena.

The available number of observation wells in the city is not enough to build a conditional large-scale map of groundwater levels, the density of points is 0.2 per 1 km^2 (fig. 1). Such a number of wells is not enough even to construct a condition map of hydroisogypsum on a scale of 1 : 50,000. In order to determine the factors of groundwater formation, take into account anthropogenic influence and make sound engineering decisions, it is necessary to carry out research on a scale of 1 : 10,000 and larger.

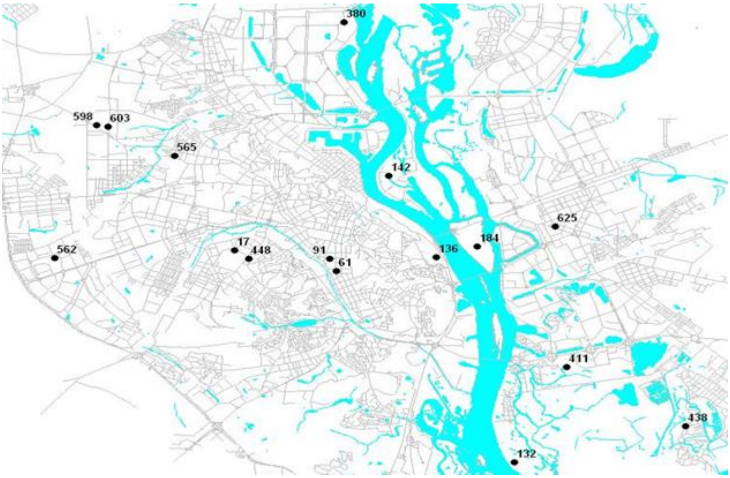

Fig. 1. Wells for monitoring the state of undergroundwater

Thus, it is not possible to build a reliable map of hydroisogypsum and to identify areas with a critical depth of the groundwater level according to the data of regular observations. Therefore, it is now extremely necessary to use stock materials, the results of engineering and geological surveys for construction in order to assess the change in hydrogeological conditions and establish the factors of formation of the groundwater regime. This will allow to increase the amount of source information without additional increase in the number of observation points on the state of the underground hydrosphere.

Obtaining an idea of the structure of the geofiltration medium and using it to assess the current state of forecasting its change is possible, as a result of the use of available stock materials for geological, hydrogeological and engineering-geological wells. In many cases, geological and hydrogeological conditions within the location of individual objects are well studied, and it is possible to use them for forecasting, which to some extent compensates for the lack of observation points (fig. 2).

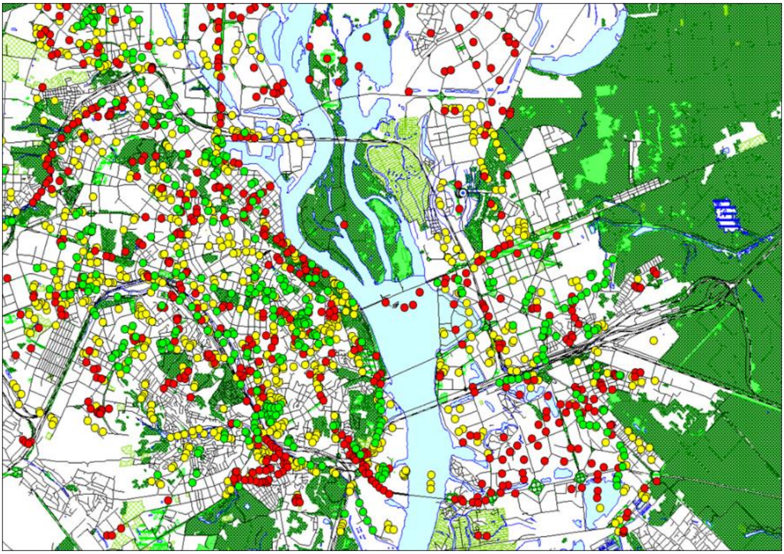

Fig. 2. Exploratory engineering and geological wells, which are advisable to use for monitoring the state of groundwater

It is possible and expedient to use such information in assessing and forecasting the state of the groundwater system, but only on the basis of geoinformation technologies[5]. Most of the original hydrogeological information is unordered and not interconnected in advance, and moreover, it was obtained at spatially unordered observation points. At present, information is an array of scattered and insufficiently systematized data, sometimes difficult to access for the user. Therefore, first of all, it is advisable to create such a base, which would allow in the future to carry out a scientifically based inventory of available data, process them, synthesize, analyze and use them for hydrogeological modeling.

[5] Chomko, D., Koshliakov, O., Dyniak, O., Koshliakova, I. Formation, distribution and movement of groundwater on the territory of compacted building in Kiev city. Abstract of XVIII International Conference on Geoinformatics. *Theoretical and Applied Aspects*. Kiev 2019, Ukraine. https://doi.org/10.3997/2214-4609.201902122

In general, the analysis and forecast of the groundwater regime in densely built-up areas is associated with overcoming a greater information barrier (due to the incompleteness and inaccuracy of hydrogeological and hydrological information) than in other filtration tasks, since the uncertainty of data on losses from water-bearing communications is added here , as well as disruption of the natural hydrogeological situation due to construction, repairs, changes in the regime of runoff from the surface of the earth and vertical moisture transfer. Added to this is the complication of calculation schemes, which must take into account the different scale of objects, the influence on the filtration regime, as well as the limitation of the territory for carrying out radical repair and preventive measures.

In order to solve the tasks, it is necessary to analyze a large amount of raw data of various topics (design maps and schemes, results of field studies, data of analyzes and calculations, etc.) and create a set of resulting materials of an evaluation, forecast and recommendation nature. A large number of these materials should be presented in the form of maps, schemes, block diagrams and other cartographic materials, which should be well compared with each other and complement each other (fig. 3).

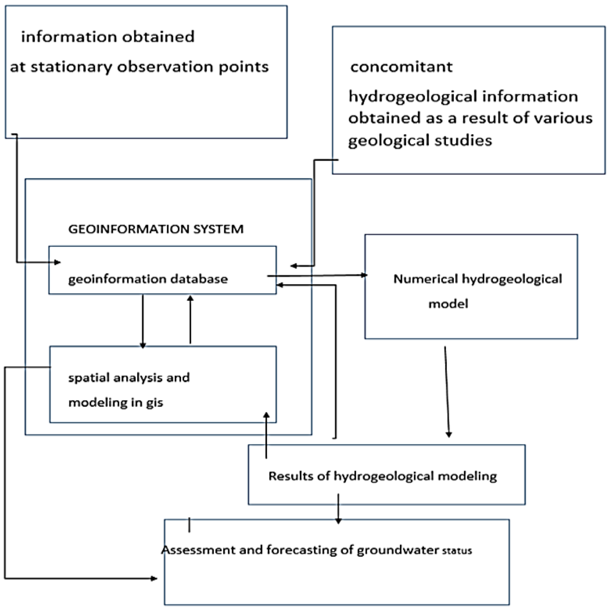

Fig 3. Scheme of realization of the concept of hydrogeological monitoring on the basis of geoinformation approach

The use of GIS technologies in the practice of forecasting the regime of underground water makes it possible to really look at the problem in a new way, to comprehensively analyze it and make highly qualified conclusions and forecasts, to prevent emergency environmental situations of anthropogenic origin.

Therefore, it is expedient to carry out the research of areas where groundwater levels fluctuate, as well as the construction of predictive maps of groundwater levels and the justification of measures necessary to maintain safe levels of groundwater, using GIS using modern methods of mathematical modeling. Data on groundwater levels should be updated in real time, for which it is necessary to have an operational system for collecting and processing the necessary information. This can be realized only with a systematic approach to organizing and conducting groundwater monitoring[6].

Currently, studies of the underground water regime on the territory of the city are carried out by various organizations, and their number and volumes do not allow to establish with sufficient accuracy the factors influencing the state of the underground hydrosphere and to develop measures aimed at preventing the development of negative processes and phenomena. Therefore, today it is only possible and expedient to create a database (based on GIS) for the purpose of scientifically based inventory of available data, systematization and processing of accumulated geological, hydrogeological, engineering-geological, geophysical information and its further use for the purpose of reproducing the surface of groundwater and creation of forecast maps of groundwater levels. At the first stage of the formation of the GIS base, it is necessary to prepare cartographic information on an electronic basis in the form of appropriate layers.

3. Experience of GIS integration with problem-oriented modeling systems for studying the state of the underground hydrosphere

From a purely scientific point of view, the role and place of modeling as a research method in the underground hydrosphere monitoring system schematically looks as follows. The functioning of the monitoring system ensures the receipt of information necessary for making management decisions in the field of rational use of groundwater and prevention or minimization of negative consequences of anthropogenic influence on the underground hydrosphere. This involves forecasting the state of groundwater under the influence of certain natural and anthropogenic factors. Such a

[6] Диняк, О., Кошлякова, І. Використання геоінформаційних баз даних для оптимізації інженерно-геологічних досліджень на урбанізованих територіях. *Вісник Одеського національного університету. Географічні та геологічні науки*. 2013. Т. 18, 1 (17). P. 67–70.

quantitative forecast requires the use of certain types of mathematical modeling.

In order to determine the location of the ground water surface on the territory at certain points in time and predict the levels of ground water, it is necessary to use geofiltration modeling methods that allow you to reproduce the surface of ground water levels at a point in time. To build a correct model, it is necessary to accurately map the territory, taking into account the geological structure, geofiltration parameters, data on the meteorological situation, as well as quantitative data on man-made load.

The most reliable forecast and assessment of the state of underground water resources is possible on the basis of deterministic mathematical models[7]. The creation of such models allows, on the one hand, to take into account natural and anthropogenic factors that have an impact on a specific object, and on the other hand, to assess the impact of the object to the adjacent territory. It should be noted that the construction of reliable deterministic mathematical models is possible in the presence of a significant amount of heterogeneous input information. Such information requires appropriate systematization, structuring, accumulation and storage. For their correct use, deterministic models require a fairly high supply of initial information, in particular, data on the filtration and capacity properties of rocks.

One of the important indicators of the formation of groundwater levels in urban areas is the intensity of infiltration nutrition[8]. The central parts of the cities, which have the highest density of buildings and the covering of squares and streets with asphalt or concrete (due to which the role of evaporation processes in water exchange is drastically reduced), especially in the absence of an organized removal of surface runoff, are characterized by the most favorable conditions for the formation of additional nutrition. Usually, this value is the maximum here.

The dependence of the regime of groundwater on atmospheric precipitation in natural conditions is known and determined using hydrogeological observations. Infiltration of atmospheric precipitation in built-up areas differs sharply from natural ones, as it is related to the conditions of closed territory, economic use, and engineering preparation. In addition, the role of precipitation in the water balance of the territory depends

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[7] Koshliakov, O., Dyniak, O., Koshliakova, I. Providing the information component of hydrogeological processes using GIS in Kiev. Abstract of 14-th International Conference Geoinformatics. *Theoretical and Applied Aspects*. Kyiv, 2015, Ukraine. DOI: https://doi.org/10.3997/2214-4609.201412407

[8] Koshliakov, O., Dyniak, O., Koshliakova, I. The application of spatial analysis and GIS modeling at the stage of solving the reverse problem in mathematical modeling of geofiltration. Abstract of XIX International Conference on Geoinformatics. *Theoretical and Applied Aspects*. Kiev 2020, Ukraine. DOI: https://doi.org/10.3997/2214-4609.2020geo056

on the absorption capacity of the soil surface. If the intensity of precipitation exceeds the hydraulic conductivity of the soil when it is fully saturated, the area is flooded. It should be noted that despite the significant influence of man-made losses on the formation of the water balance of the underground hydrosphere, the groundwater regime is mainly determined by atmospheric precipitation. The infiltration load, both seasonally and perennially, reflects periods of rain and snowmelt. The regularities of the underground water regime in built-up areas are, as a rule, functionally related to the large volume and time of rains and are manifested in large areas. Usually, during construction, precipitation contributes to an increase in the additional supply of groundwater, mainly due to surface runoff. At the stage of operation, atmospheric precipitation has a much smaller effect on the change of the water regime, mainly due to the covering of the ground surface with asphalt, concrete, and the organization of surface runoff. When assessing the impact of precipitation on fluctuations in the groundwater level, it is necessary to take into account such an indicator as the power of the aeration zone, since a significant part of it can go to saturate the pore space of the soil.

The issue of estimating evaporation and transpiration for built-up areas has not been studied enough. Within the territories of urban development, evaporation and transpiration are significantly complicated due to the specific wind regime, shading conditions, the presence of asphalt pavement, the presence of buildings and structures. In city parks, where the main mass of vegetation is concentrated, transpiration depends on the same reasons as in an ordinary forest massif.

Factors determining evaporation from the soil surface can be divided into three main groups:

1) meteorological (air temperature and humidity, solar radiation balance, wind);

2) soil (albedo, microrelief, temperature, humidity, hydro and thermophysical properties, porosity, hydrophobicity, moisture conductivity, heat capacity);

3) factors caused by human activity (tillage, arrangement of coverings, man-made precipitation).

In contrast to the conditions formed in natural conditions, man-made factors (drainage systems, water intakes, artificial aquifers or their destruction) cause the strengthening or termination of vertical water exchange with the lower and overlying aquifers (upward flow; downward flow). Regulated water exchange with the lower and overlying aquifers is ensured by special drainage systems. The intensity of water exchange processes depends on the geofiltration section of the water exchange zone, the intensity of the additional infiltration load and the underground water intake.

The value of water losses from water-bearing communications is usually taken into account as distributed over all areas of research, if they are not of a special nature. The inflow of water into the soil depends on the area distribution of water-bearing networks, their diameter, material and service life. The hydrodynamic process is aimed at replenishing underground water reserves and raising their level. The reaction of the geological environment in the event of water loss from aquifers depends primarily on the geofiltration section and the nature of the boundary conditions. It should be noted that a direct relationship between the volume of water-bearing communications and the amount of water entering the soil is not always traceable. In the territories of urban buildings, losses from water-bearing communications are significant and affect the change in water exchange conditions. As a rule, domes of underground irrigation of soils are formed in places of concentration of communications.

Condensation of moisture in the soil occurs in areas of the built-up area covered with asphalt, concrete and other coverings, as well as under buildings and structures. Saturation of soils with moisture to the maximum moisture content contributes to the complete discharge of infiltration waters to the groundwater level. Observations show that the moisture content of the upper soil zone increases by 8–10 % under the asphalt coating. Condensation and water exchange associated with this phenomenon increase simultaneously with the increase in the volume of construction work.

The maximum infiltration losses of surface runoff water are observed at the stage of engineering preparation of the territory and construction work, when the natural paths of surface runoff are eliminated and a long gap is created between earthworks of the zero cycle, which causes the accumulation of surface water in construction pits, trenches and near retaining walls. Minimal infiltration losses of surface water are typical for the stage of operation, when the construction of concrete coatings is finished and the stormwater collection network is created. Penetration of rainwater and meltwater into the soil can still occur on the contours of buildings, through backfill pockets, and on open areas. In this case, infiltration losses depend on the building density. Regulation of surface runoff is carried out with the help of vertical planning before the beginning of construction, while it is necessary not to leave pits and trenches open for a long time, to ensure their drainage, to create an urban and industrial stormwater system. All these measures will significantly reduce the impact of anthropogenic factors on the conditions of groundwater supply and their water exchange regime.

To reduce the infiltration of water into the soil from artificial reservoirs and watercourses, waterproofing screens are installed. However, the degree of reliability of these screens is not always sufficient. Therefore, artificial reservoirs are always a source of additional groundwater supply. Groundwater levels near such reservoirs are higher than in the surrounding areas. The share of groundwater supply due to losses can be quite significant and lead to a change in the water exchange basin, especially in the areas of reservoirs and large main channels.

The supply of water for irrigation of green areas in quantities greater than the calculated norms causes infiltration of irrigation water and related processes of intensification of water exchange[9]. Especially large losses of irrigation water occur on plots of individual buildings.

Sewage networks are pressureless, laid at a great depth. They can work as drains in case of flooding. The share of water drainage by the sewage and collector network can be determined using special observations or calculations.

In the territories of industrial and urban agglomerations, in order to ensure their economic activity, numerous water intakes are operated, which in terms of intensity of influence act as one of the leading factors of water exchange. Water intakes have an impact on a significant underground space, drawing filtration flows to the places of their installation. The change in water exchange can be so significant that traces of the natural regime disappear, and boundary conditions also change.

The reliability of the results obtained with the help of mathematical modeling depends mainly on the reliability of the original natural mathematical geofiltration model. When checking the reliability of the model, the existing natural surface of groundwater levels (data on groundwater levels at observation points) acts as a benchmark.

The map of hydroisogypsum in the first approximation can be obtained using geoinformation systems to determine the main features of the flow of groundwater and reject or correct those initial data that contain significant errors.

It is advisable to check the adequacy of the model by performing computer modeling based on GIS. (Fig 4).

The main practical limitation in the application of most mathematical models is related to their insufficient spatial differentiation. Any indicator or equation obtained for some territory (area, district) does not yet provide an idea for the change of this indicator or equation from one place to another within the given area or district. When monitoring, it is important not only to

[9] Koshliakov, O., Dyniak, O., Koshliakova, I. Technogenic infiltration nutrition component underground water as a factor the emergence and activation of dangerous exogenous processes in industrial and city agglomerating territories. Abstract of 11th International Scientific Conference on Monitoring of Geological Processes and Ecological Condition of the Environment, Kyiv, 2017, Ukraine.

obtain a mathematical model, but also to present it cartographically, reflecting changes in mathematical dependencies between objects from one place to another, tying them to elementary (or characteristic) units of territorial division. That is, the groundwater monitoring system also requires the use of mathematical and cartographic modeling.

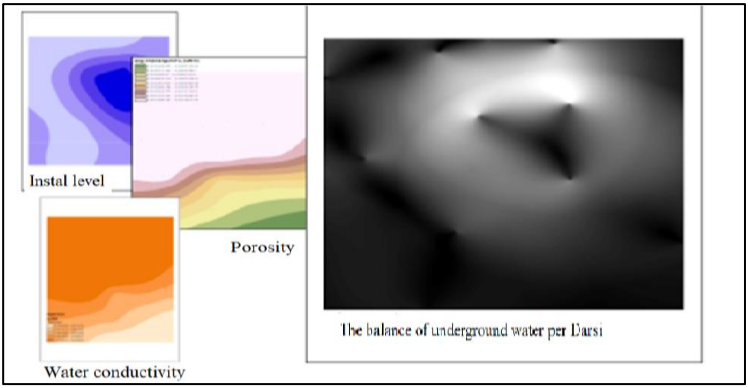

Fig. 4. The check of the geofiltration model by balance

In mathematical and cartographic modeling, along with the construction of relatively simple models (the simplest are isoline maps, cartograms, cartodiagrams, etc.), more complex ones are often used, which require many transformations of mathematical dependencies into a cartographic form and vice versa. Such modeling uses the properties of mathematical and cartographic models in the process of analysis-synthesis of complex spatio-temporal information. The cartographic component continues and develops the mathematical model[10]. It transforms the initial (initial) information in accordance with the purpose and objectives of the research. The cartographic presentation of mathematical calculations makes it possible to visualize their results in a form that is optimal for further research.

CONCLUSIONS

Agreements that entered into force in connection with the association of Ukraine with the EU require the adoption of appropriate management decisions. This can be done on the basis of monitoring information received and processed according to European directives and standards. But there is no

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[10] Диняк, О., Кошлякова, І. Картогафічне моделювання та ГІС при дослідженні розвитку небезпечних геологічних процесів. *Проблеми гідрогеології на сучасному етапі* : матеріали І наукової конференції, Харків, 2014. С. 88–89.

modern monitoring system in the country, it is only about its organization mainly at the design stage or implementation at the level of individual pilot projects.

The organization of a modern underground hydrosphere monitoring system for the present time in Ukraine requires significant material costs for its rational scientific justification, design, creation and operation.

Currently, in Ukraine, the practical obtaining of information necessary for making management decisions in the field of rational use of groundwater and prevention or minimization of the negative consequences of anthropogenic influence on the underground hydrosphere occurs mainly at the expense of the existing stationary network of hydrogeological regime observations and individual temporary observation points. It should be noted that the aforementioned stationary observation network is now in an extremely neglected state and is constantly shrinking, including as a result of military operations. In turn, the number and spatial location of temporary observation points is determined primarily by the available meager funding, and not by real necessity. The basic cartographic information used in the monitoring system (for example, hydrogeological and other special maps) is usually extremely outdated.

Such shortcomings prevent effective monitoring of the geological environment and effective assessment of the state of natural and man-made systems in order to ensure an acceptable level of environmental safety.

It follows from the above that the current state of application of modeling in the monitoring system cannot be of an information-based, systematic and consistent nature. Accordingly, the accuracy of the forecast carried out with the help of such modeling is usually low. Obviously, this can have a negative impact on the validity of management decisions.

However, from the real situation that has developed with the use of modeling in the underground hydrosphere monitoring system, one should not draw a conclusion about the impracticality or prematureness of its practical application. According to the authors, such application will be correct provided that certain rules are taken into account, which allow to increase the validity and objectivity of the obtained results.

1. It should be assumed that the goal of modeling is an objective forecast of the state of groundwater under the influence of certain natural and anthropogenic factors. In turn, the forecast is of two types – the forecast as a prediction and the actual forecast.

2. Usually, when choosing a type of modeling, hydrogeologists prefer deterministic mathematical modeling as the most suitable for actual forecasting. However, taking into account the availability of factual information, the possibility of its new acquisition and the cost of such works,

at present deterministic mathematical modeling in most cases is unlikely to be performed in full. In the best case, its results will reveal trends (qualitative trends) that correspond to the forecast as a prediction.

3. Establishing general trends can also be done using statistical modeling, which, unlike deterministic, is much cheaper.

5. The advantage of using GIS also lies in the possibility of creating, maintaining and constantly updating (updating) the database of input data for underground hydrosphere monitoring. The development of a scientifically based methodology for assessing the state of geological systems is a very urgent and difficult task. The starting point can be an idea of the hydrogeological systems of groundwater from the standpoint of assessing the resistance of such systems to external influences. Over time, the accumulated information will make it possible to perform the actual forecast using deterministic mathematical modeling.

SUMMARY

Huge economic losses and risks of manifestation of dangerous processes are due to long-term ignoring of interdependent issues of hydrogeological and ecological justification of economic and construction activities in modern megacities.

The state of natural-anthropogenic geosystems is generally determined by a number of factors, among which the priority is the state of groundwater. Anthropogenic load on the state of the underground hydrosphere requires the use of specific approaches and methods of monitoring the underground hydrosphere in order to ensure an acceptable level of environmental safety. Changes in the geological environment in the process of urbanization, determination of the conditions and factors for the formation of groundwater in urbanized areas, require consideration of the peculiarities of creating a system and conducting monitoring in such areas. Today, such a system does not exist. The most reliable forecast and assessment of the state of underground water resources is possible on the basis of deterministic mathematical models, but there are difficulties with providing parameters. The groundwater monitoring system also requires the use of mathematical and cartographic modeling. The use of GIS technologies in the practice of forecasting the regime of underground water makes it possible to really look at the problem in a new way, to comprehensively analyze it and make highly qualified conclusions and forecasts, to prevent emergency environmental situations of anthropogenic origin.

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