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Analysis of Influence of Endogenous Factors on Results of Geoecological Express-Control of Water Resources

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Abstract: The study presents the organization of geo-environmental monitoring system decentralized water supply, analyzes the effect of endogenous factors on the results of geo-environmental monitoring of decentralized water supply using geoelectric express control methods. Groundwater regime depend on a variety of geological, hydrogeological, geomorphological and other conditions. The main factors include of forming mode lunar-solar perturbations which directly affect the level of groundwater and deformation of rocks. Spectral analysis showed that there is a connection between fluctuations in the groundwater level with diurnal and semidiurnal tides. Especially, this relationship manifests itself in the aquifer with low porosity. This dependence should be considered in the simulation in order to remove endogenous interfering in the results of geoenvironmental monitoring of groundwater.

Key words: Aquifer, endogenous factors, monitoring system, express control, geoelectric methods, algorithm of data processing

INTRODUCTION

In connection with the provision and maintenance of ecological safety in towns and cities all the more urgent task of operational control of the use and evaluation of the quality of groundwater. Especially, it is important in towns and regions using decentralized water supply system. On the territory of the Russian Federation has developed and operated geoenvironmental monitoring at various levels of the system, under which carried out regular monitoring of public water supply (Alekseyev, 2004; Belousova, 2001). In other countries such as the United States and drinking water quality parameters are normalized and monitored in public water supply systems level (primary NPDWP standards). The National Secondary Drinking Water standards (NSDWP) which are not binding on the federal level but can be taken as binding decisions of the state authorities. They normalize the water quality of decentralized sources (Belousova *et al*., 2006).

However, conducted socio-hygienic monitoring of decentralized water supply and unscheduled inspections which are aimed at preventing the harmful impact of unsafe drinking water on public health, allow only reveal part of the violations and inconsistencies (Bykov and Kuzichkin, 2014a). Very little published data on the quality of water used for drinking purposes, produced from private wells and wells located in the local area. They are as a rule are not included in the monitoring program and the monitoring function at the moment is actually assigned to the user (Bykov and Kuzichkin, 2014b). There are now also implemented methods of express-control such as geoelectric control, the organization of geoenvironmental monitoring of decentralized water supply (Dorofeev *et al*., 2012). Geoenvironmental monitoring system decentralized water supply that is based on geoelectric sounding methods is highly sensitive to changes in the electrical conductivity of the upper aquifer. However, the consequence of increasing the sensitivity of the data is dependent geoelectric measuring system by endogenous and exogenous factors. Of particular note are the lunar-solar tidal perturbation which are essential for disturbing factors during the water resources of the express control geoelectric methods. It is known that they cause on the earth's surface of deformation of compression and stretching that on intensity of impact on the top part of crust can serve as an analog of processes of compression and stretching at tectonic activization (Dorofeev *et al*., 2012).

The purpose of research is studying and the analysis of influence of endogenous factors on results of geoenvironmental monitoring of decentralized water supply at the local level with application of geoelectric methods of express-control.

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MATERIALS AND METHODS

Organization of the system of geo-environmental monitoring decentralized water supply: Geo-environmental monitoring system decentralized water supply is fundamental to the structure of environmental protection and rational nature and is used in conjunction with other sub-systems of environmental monitoring. It is for them to spatial data sources and she uses the data from these systems as the attribute information (Epishin *et al*., 1985). The purpose of geo-environmental monitoring system decentralized water supply is constant monitoring of the dynamics and quality of the upper aquifer water and to ensure rapid detection of crisis situations. The basis of its construction is the geoelectric methods of express analysis of the upper aquifer by the generalized parameter-electrical conductivity. Choosing water conductivity as a generalized water quality parameter is determined by its information content and high processability geoelectric methods to control this parameter in real time. Besides, it gives the chance of use of the distributed geoelectric measurements for hydrogeological assessment of development of endogenous geological processes in the controlled territory (Korochentsev *et al*., 2013).

In points of observation according to registration of parameters of a geoelectric section the following indicators have to be controlled:

- Mineralization of the aquifer used for water supply
- The state of the groundwater
- Temperature regime of groundwater in the area of observation

A special feature is the control of the spatial limitations of the data collection and evaluation of not only the geoelectric section parameters in the field of observation but also on the hydrogeological model (Kuzichkin and Chaykovskay, 2011). The principle of decentralized water supply control system based on geoelectric methods, taking into account the influence of factors for disturbing is shown in Fig. 1.

Initialization processing system geoelectric data upper aquifer is carried out on the basis of the formation of the vector model MS parameters for hydrogeological protection zones of control. The data model parameters are determined on the basis of preliminary exploration data in accordance with the basis of geodynamic models MD and GIS data-server MG. When initializing the system matched filtering parameters of the main aquifers and share their low permeable layers, notes areal groundwater recharge and discharge, temperature parameters. The hydrogeological parameters are recorded in the database and models used in the simulation (Kuzichkin, 2012).

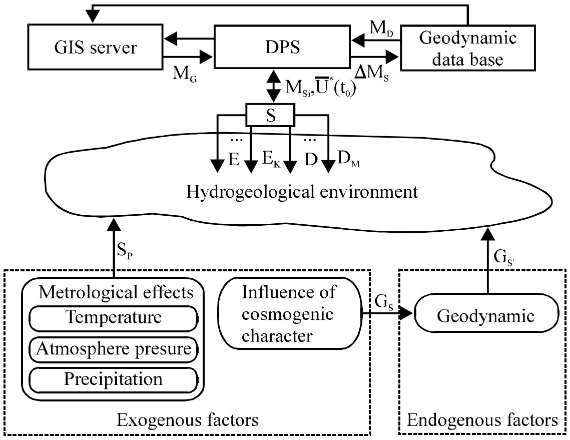

Fig. 1: The structure of the aquifer monitoring system

Table structure separately allocated exogenous and endogenous factors affecting the aquifer. Meteorological (exogenous) effects S_p have a seasonal effect on the upper aquifer, changing the groundwater level in the period of floods and high water content in the spring and irregular, changing the hydrochemical composition defined by ingress of surface water and groundwater. Effect of temperature on the hydrodynamic regime of underground water appears in the freezing of the aeration zone, the obstacles in the winter feeding of groundwater, evaporation of the unsaturated zone and the surface of the ground water. Geodynamic impact cosmogenic character G_S manifested in the changes under the influence of gravitational forces of the sun and the moon, causing elastic deformation of the crust which in turn entails change in groundwater levels. The highest tides observed in nearby points to the moon of the earth-in positions of upper and lower culminations and especially during the full moon, when the effects of the moon and sun are added (Anonymous, 1998).

Geoelectric methods of geoecological express-control of the aquifer: Modern control systems built on the basis of the geoelectric methods of probing the subsurface provides highly accurate tracking of geodynamics environment and can prevent the emergence of possible crisis situations during the geoenvironmental monitoring (Orekhov and Dorofeev, 2014). To monitor the status of the aquifer, geoelectric methods have several advantages over other geophysical methods due to the fact that the electrical resistivity of water-saturated rocks is very different from the electrical resistance of dry rocks

(Petrochenkov, 2005). This property rocks and determine the effectiveness of using geoelectric methods for assessing the state of the aquifer. Additionally, groundwater geochemical activity involves dissolution of contaminants. Both of these processes cause a change in the physical properties of the geoelectric and geologic section and therefore, can be detected by the system of geoenvironmental monitoring decentralized water supply using geoelectric methods of express-control.

As the base model in the organization of geoenvironmental monitoring of the upper aquifer in the monitoring of non-centralized water supply systems can be adopted multi-layer model of the geological section. In the simplest case, this model is a two-layer conductive half-space which can describe the process of control of the upper aquifer. Groundwater which contain mostly inorganic compounds conductivity is a measure of the total ion concentration. Mineral make up the main part of the water ions: Na^+, K^+, Ca_2^+, Mg_2^+, Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-. With increasing concentration of salts in the water amplified interionic interaction. Speed of movement of the ions at the same time reduced due to cataphoretic effect. The conductivity of aqueous systems increases with temperature, since, this decreases the viscosity and increases the degree of dissociation. The evaluation result of total mineralization of water in terms of its conductivity is ambiguous. The main problem in such cases is caused by wide variations in the chemical composition of surface waters, occasioning unequal electrical conductivity of various salts. In this regard, the level of salinity and conductivity parameters fluctuate widely. Therefore, the use of the method of geoelectric express control of the aquifer and the multilayered parametric geoelectric model will highlight variations in the size and electrical conductivity of several layers simultaneously. It is a distinctive feature of the proposed approach (Romanov *et al*., 2015a). When using a point source of geoelectrical field potential at a distance from the source it can be written as follows in Eq. 1:

$$U(p)=\frac{\rho_1(p)I(p)}{2\pi}\left\{\frac{1}{r}+\int_0^{\infty}\left[R_1(m)-1\right]J_0(mr)dm\right\} \quad (1)$$

Where:

$J_0(mr)$ = Bessel function of the first kind of zero order
mr = The geoelectric contrast function
N = The layered geological section:

$$R_1(m)=\text{cth}\left[mh_1+\text{arcth}\frac{\rho_2(p)}{\rho_1(p)}\left[\text{cth}\left[mh_1+\text{arcth}\frac{\rho_2(p)}{\rho_1(p)}\right]\right]\times\right.$$
$$\left.\text{cth}\left[mh_3+,\ \dots,+\text{arcth}\frac{\rho_{n-1}(p)}{\rho_n(p)}\right]\right]\dots\Bigg] \quad (2)$$

After replacement $R'_1(m) = R_1(m)-1$ we get:

$$U(p)=\frac{\rho_1(p)I(p)}{2\pi}\left\{\frac{1}{r}+\int_0^{\infty}R'_1(m)J_0(mr)dm\right\} \quad (3)$$

Assume the existence of a common depth measure d_0. The power of any layer in our model: $d_i = n_id_0$; where $n_i\in Z$.

For the function of the geoelectric contrast can be obtained by expression as an infinite sum of exponents (Romanov *et al*., 2015b; Romanov and Kuzichkin, 2014, 2015):

$$R'_1(m)=1+2\sum_{i=1}^{\infty}q_ie^{-2imd_0} \quad (4)$$

where q_i is emission factor which can be calculated for any value i on the set parameters of multilayer section. As seen from the ratio function geoelectric contrast $R'_1(m)$ depends only on the parameters h_ip_i cut and independent of r.

When using non-contact sensors of the electric field and the normalization of the recorded signal geoelectric proceed to the transfer function of the geoelectric section:

$$H(p)=-\frac{\partial U(p)}{\partial rI(p)}=\frac{\rho_i(p)}{2\pi}\left[\frac{1}{r^2}+\int_0^{\infty}R'_1(m)mJ_1(mr)dm\right] \quad (5)$$

Accordingly, the transfer function of the geoelectric section can be expressed as an infinite sum of elementary functions:

$$H(p)=\frac{\rho_i(p)}{2\pi}\left[\frac{1}{r^2}+2\sum_{i=1}^{0}q_it_{i,E}\right] \quad (6)$$

where $t_{i,E}$ is the removal coefficients which aren't depending on resistance of the horizons, determined by the following ratio:

$$t_{i,E}=r\Big/\left[r^2+(2id_0)^2\right]^{3/2} \quad (7)$$

For example, for a two-layer geoelectric section with parameters h_1, $\rho_1(p)$ for the first layer, h_2, $\rho_2(p)$ for the second layer, the coefficient of issue can be expressed through coefficient of contrast of electric parameters of Eq. (8):

$$q_i(p)=k_{12}^i(p)=\left(\frac{\rho_2(p)-\rho_1(p)}{\rho_2(p)+\rho_1(p)}\right)^i=\left(\frac{\sigma_2(p)-\sigma_1(p)}{\sigma_2(p)+\sigma_1(p)}\right)^i \quad (8)$$

Taking $d_0 = h_1$, we get:

$$H(p)=\frac{\rho_1(p)}{2\pi}\left[\frac{1}{r^2}+2\sum_{n=1}^{\infty}\frac{k_{12}^n(p)}{\left[r^2+(2nh_1)^2\right]^{3/2}}\right] \quad (9)$$

Similarly, it can be prepared the design for the ratio gain for any number of layers carried geoelectric model of geological section at the rapid control of decentralized water supply aquifer.

RESULTS AND DISCUSSION

Features of the groundwater regime depend on a variety of geological, hydrogeological, geomorphological and other conditions. The main factors formation of regime include lunar-solar perturbations which directly affect the level of groundwater and deformation of rocks.

As is known (Romanov *et al*., 2015a) due to the daily rotation of the earth and the movement of the moon and the sun in their orbits, tide-force at every point on the earth's surface is constantly changing over time, it is necessary to take into account when analyzing the change in the level of groundwater.

Changes in the volume of micropores, capillaries and microcracks entails a change in the volume ratio of the pore and gravitational water in aquifers. Depending on the parameters of aquifers level variations can reach values of several to several tens of centimeters. Water level changes in areas located far from the sea, well described by cyclical fluctuations. The impact of the tides is especially clearly manifested in aquifers that have low porosity.

Tides are the result of the visco-elastic deformation of the earth by the gravitational attraction of the moon and the sun. It is known that the five main types of waves cause almost 95% of the variation in water level in aquifers. These waves can be divided into two groups: those with a daily tesseral wave period and wave sector semidiurnal period (Table 1).

Calculation of the spectral power density allows to identify the frequency of the periodic signal. The relative power spectral density was calculated for a simulated tidal and filtered observations of the water level (Fig. 2).

Diurnal and semidiurnal tides occur at frequencies f1 and f2 (Table 2). The periods of these cycles correspond exactly to the diurnal waves O1 and K1 and semi-diurnal waves N2 and M2. Observations have shown a link between the recorded groundwater levels and tides.

Spectral analysis showed that there is a connection between fluctuations in the groundwater level with diurnal and semidiurnal tides. Especially, this relationship manifests itself in the aquifer with low porosity. This dependence should be considered in the simulation in order to remove endogenous interfering in the results of geoenvironmental monitoring of groundwater.

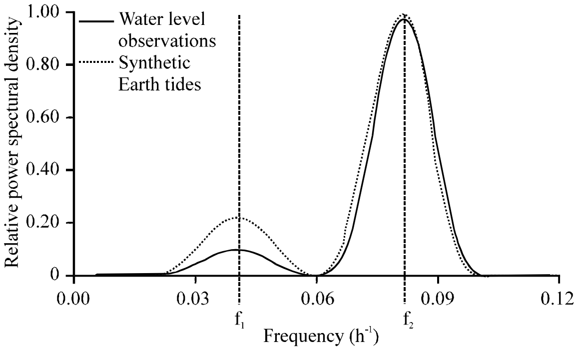

Fig. 2: The relative power spectral density of the observed tide

Table 1: Origin, periods and frequency of basic tidal fluctuations

Designations	Rate (deg/h)	Period (d)	Origin
Mf	1°098'033	13.66	Lunar, variation of declination
O1	13°934'036	1.07	Lunar, main term-tesseral
K1	15°041'069	0.99	Lunisolar, main term-tesseral
N2	28°439'730	0.53	Lunar, main term (orbital ellipsoid)-sectorial
M2	28°984'104	0.52	Lunar, main term-sectorial
S2	30°000'000	0.42	Solar, main term

Table 2: The characteristics of the observed frequency signals

Frequencies	Periods	Tides
$f1 = 0.04109\ h^{-1}$	P1 = 24.34 h (1.01 day)	O1, K1
$f2 = 0.08009\ h^{-1}$	P2 = 12.48 h (0.52 day)	N2, M2

The algorithm of data processing: At each point of transfer ratio control (Eq. 10) can be represented as the sum of the nominal average over the entire period of observation T and variable part, determined by the geodynamic changes in the environment $\bar{\alpha}$ and endogenous interference $\bar{\beta}$:

$$H_i(p) = H_i(0) + \Delta H_i\left(p, \bar{\alpha}_i, \bar{\beta}_i\right) \tag{10}$$

Based on the analysis of endogenous influence can be written to the variable part:

$$\Delta H_i\left(p, \bar{\alpha}_i, \bar{\beta}_i\right) = \sum_{k=1}^{K} \alpha_{ik} \frac{\partial H_i}{\partial \alpha_{ik}} + \beta_{1i} \cos(\omega_1 t + \varphi_1) + \beta_{2i} \cos(\omega_2 t + \varphi_2) \tag{11}$$

where $\partial H_i/\partial \alpha_{ik}$, it makes sense to geodynamic sensitivity, determined on the basis of preliminary calculations. The principle of removing endogenous influence based on an algorithm involving decomposition quasistationary observation interval on geodynamic section. Inside each time section:

$$H_i(0) + \sum_{k=1}^{K} \alpha_{ik} \frac{\partial H_i}{\partial \alpha_{ik}} \approx \text{const} = a_n \tag{12}$$

In this case, the minimization function to obtain the regression analysis assuming registration points within the interval (Zatsepina, 1988):

$$\Psi_i = \sum_{n=1}^{N}\sum_{j=1}^{M}\begin{pmatrix} H_{ij}\text{-}a_n\text{-}\beta_{1i}\cos\varphi_1\cos\omega_1 t+ \\ \beta_{1i}\sin\varphi_1\sin\omega_1 t\text{-}\beta_{2i}\cos\varphi_2\cos\omega_2 t+ \\ \beta_{2i}\sin\varphi_2\sin\omega_2 t \end{pmatrix}^2 \quad (13)$$

As a result, we obtain a system of N+4 as shown in Eq. 14:

$$\begin{cases} \dfrac{\partial\Psi_i}{\partial\alpha_n} = 0 \\ \dfrac{\partial\Psi_i}{\partial(\beta_{1i}\cos\varphi_1)} = 0, \dfrac{\partial\Psi_i}{\partial(\beta_{1i}\sin\varphi_1)} = \end{cases} \quad (14)$$
$$0, \dfrac{\partial\Psi_i}{\partial(\beta_{2i}\cos\varphi_2)} = 0, \dfrac{\partial\Psi_i}{\partial(\beta_{2i}\sin\varphi_2)} =$$
$$0, (n = 1, ..., N)$$

Solving the system of equations for the vector geodynamic variations, we eliminate endogenous effect on the results of geoenvironmental monitoring

CONCLUSION

The proposed method has been tested at the control of the aquifer on geodynamic testing ground lake holy, N. Novgorod Region. The observation time was 4 months to 12 May 2016 on 12 September 2016. Interval geodynamic quasistationarity was chosen to be 3 O'clock. As a result, it managed to significantly reduce the endogenous effect on the results of geoenvironmental monitoring. Estimated value of the noise reduction level for the geoelectric signal was 14.6 dB.

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