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Vulnerability assessment of drinking groundwater of buchak-kaniv aquifer under the conditions of quality composition long-term transformation

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ABSTRACT

Problems Statement and Purpose. This article is a continuation of the authors' previous publications on improving the methodical approach to assessing the vulnerability (protection) of drinking groundwater within the Dnipro-Donetsk artesian basin (DDAB) and is a practical component of these studies. In order to find and develop optimal forms of ecological safety management of drinking water supply for the region population, the authors' improved approach to assessing the vulnerability (protection) of drinking groundwater in the strategically important waters of buchak-kaniv aquifer (BKA) was tested.

The purpose of article is the ecological and hydrogeological zoning of research area according to the danger of quality transformation of BKA groundwaters and the determination of zones of increased ecological danger of these waters quality reduction due to elements of surface and deep genesis.

Data & Methods. The research is based on the analysis of results of drilling more than 950 wells in this region, as well as about 500 measurements of piezometric levels of BKA and the first interlayer aquifer during 1960-2020.

Results. Complex systems of ecological and hydrogeological zoning of the territory of DDAB central part have been developed according to the degree of ecological danger of lowering the quality of BKA drinking groundwater.

Zoning of the territory was carried out according to the danger of deterioration of these waters quality by man-made pollutants that enter the waters in the process of downward vertical filtration and migration from the earth surface. Ecologically dangerous areas with a potential decrease in the quality of BKA drinking groundwater due to elements of surface genesis (water intakes of Poltava, Lubny, Myrhorod, Velyka Bagachka, Krasnograd cities and some others) have been identified.

Zoning of the territory was carried out according to the danger of deterioration of the BKA groundwater quality due to the upward migration of natural deep substandard waters. Ecologically dangerous areas with a potential decrease in groundwater quality due to elements of deep genesis (water intakes of Poltava, Romodan, Myrhorod, Shyshaky, Opishnia, Gadyach, Krasnograd, Karlivka cities and some others) have been identified.

It is recommended to develop measures to increase the ecological safety of the population's drinking water supply: hydrogeochemical monitoring of characteristic indicators of water quality composition and optimization of the powerful water intakes operating modes (within ecologically dangerous territories); creation of new water intakes (within ecologically safe territories).

Keywords*: groundwater, vulnerability, protection, methodical approach, deterioration of quality, environmental safety.*

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Introduction. Creating conditions for reliable safety of people's lives and activities in terms of providing the population with high-quality drinking water is one of the priority environmental problems for Ukraine. It is especially acute in the eastern regions of country, where under the complex influence of significant man-made pressure on the geological environment (GE) and natural factors, significant quality and resource changes of surface and drinking groundwater are observed.

The peculiarity of Dnipro-Donetsk depression is its complex tectonic structure together with the modern geodynamic activity of the earth's crust. Along with this, the urbanized areas of region are characterized by significant technogenic pressure on groundwater due to the intensification of water withdrawal and the expansion of water intakes network. Within Eastern Ukraine, one of the main sources of drinking water supply for the population is groundwaters of buchak-kaniv aquifer (BKA), which are vulnerable to both man-made and natural pollution. This is manifested recently in the deterioration of these waters quality at many city water intakes against the background of modern technogenesis and natural processes.

In the conditions of finding and developing optimal forms of managing the ecological safety of drinking water supply for the population, it is urgent to determine the zones of increased ecological danger of lowering the BKA groundwater quality by ele-

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ments of surface and deep genesis due to the appropriate ecological and hydrogeological zoning of research area.

Analysis of previous studies and publications. Important publications in which the ways of pollutants migration of natural and technogenic genesis into groundwater were investigated are the papers of Ukrainian and foreign researchers A.S. Boguslavskyi (2007), V. N. Bublias (2007), V. M. Goldberg (1983, 1987), S. M. Yelokhina (1983), T. V. Yemchuk (2011), I.S. Zektser (2004), A. V. Kononenko (2017), O. E. Koshliakov (2014), V. A. Myronenko (1990), M. S. Ognianyk (2001, 2013), N. P. Osokina (2016), O. A. Ostroukh (2013), L. M. Rogachevska (2002), N. V. Rogovska (1976)), D. F. Chomko (2000), V. M. Shestopalov (2007), M. Civita (2004), M. De Maio (2004), S. S. D. Foster (1987), J. Margat (1968, 1970), M. Olmer (1974), V. Rezac (1974), M. Vrana (1968), J. Vrba (1994), A. Zaporozec (1994) and others.

Thanks to these studies, a modern methodological base for assessing the vulnerability (protection) of drinking groundwater was developed, a classification of hydrogeological "windows" was created for various technogenic and geological conditions, vertical and lateral migration paths of pollutants to drinking groundwater were determined, etc.

The modern methodological base for assessing the vulnerability (protection) of drinking groundwater is sufficiently wide and diverse. Table 1 shows the analysis of publications with the most used of existing methods, taking into account ecological and hydrogeological factors of vulnerability (protection) of these waters.

Highlighting previously unresolved parts of the overall problem. The authors of article in previous publications [4, 6] improved the methodical approach to assessing the vulnerability (protection) of Dnipro-Donetsk artesian basin (DDAB) groundwater. These papers involved the rational integration of existing methodological base, highlighting its strengths and weaknesses, and improving the latter.

This article is a continuation of these studies and is a practical component of them. The buchak-kaniv aquifer groundwaters are one of strategic reserves of drinking water within Eastern Ukraine. However, BKA is locally vulnerable to both man-made and natural pollution. Against the background of modern technogenesis and natural processes, the chemical composition of these waters has recently undergone significant changes. Currently, these waters are partially or completely unsuitable for drinking purposes at about 20 powerful urban water intakes in the region. In order to develop appropriate measures to improve the ecological safety of drinking water supply for the population of this territory, it was necessary to identify areas with groundwater that are vulnerable to technogenic and natural factors of pollution. The authors tried to solve this problem by conducting an approbation of developed approach to vulnerability assessment in the BKA waters.

The purpose of article is the ecological and hydrogeological zoning of research area according to the danger of quality transformation of BKA groundwaters and the determination of zones of increased ecological danger of these waters quality reduction due to elements of surface and deep genesis.

Scientific novelty of conducted research:

- for the first time, complex systems of ecological and hydrogeological zoning of research area according to the danger of groundwater qualitative composition transformation were developed on the basis of protection point assessment of these waters from pollutants;

- received further development of the use of multifactorial analysis in ecological and hydrogeological mapping for the selection of zones of increased ecological danger of drinking groundwater quality reduction by elements of surface and deep genesis.

Practical significance is the ecological and hydrogeological zoning of studied territory, which allows for the development of effective measures to improve the ecological safety of population's drinking water supply within each of the zones (hydrogeochemical monitoring, optimization of water intake operation modes, creation of new water intakes).

Data and research methods. These studies are based on the analysis of results of drilling more than 450 wells, which were drilled for BKA, and more than 500 for the overlying aquifers, as well as about 500 measurements of piezometric levels of nearby target and first interlayer aquifers during 1960-2020 (according to the reported materials of "Pivdenukrgeology" and fund materials of "Geoinform of Ukraine").

In previous publications [4, 6], to develop an approach to assessing the vulnerability (protection) of groundwater in the studied area, the authors used index-rating assessment methods as the basis. These methods were improved on the basis of a rational integration of various indicators characterizing the modern natural and technogenic conditions of the territory (lithological, hydrogeological and neotectonic conditions), and the selection of the most representative of them. The paper presents the results of approbation of this approach on BKA drinking groundwater.

Research results and their analysis. As was established by the authors in previous papers [5, 14], in modern ecological and hydrogeological conditions, there is a transformation of BKA groundwater chemical composition towards the quality deterioration within researched area. The general ecological conditions of BKA groundwater at large water intakes of Eastern Ukraine during the period of active GE techno-

Table 1

Analysis of the most used methods for assessing the vulnerability (protection) of drinking groundwater

Method	Who developed and/or used methods	Advantages of methods	Disadvantages of methods
Hydrogeological zoning	Foreign: M. Albine in France, M. Vrana and M. Olmer in the Czech Republic, O. Sililo and others in South Africa [20], D. Ball et al. in Scotland [18]. Ukrainian: V. M. Shestopalov and others [15].	- Versatility, which is manifested in possibility of choosing ecological and hydrogeological parameters that are necessary for the given hydrogeological conditions of studied territory; - possibility of taking into account both the lithologic and filtration factors of vulnerability (protection), and changes in intensity of man-made pressure on the GE; - clarity and ease of use in presence of powerful GIS systems.	- It is necessary to have a very significant volume of actual geological and hydrogeological data for the research region, which is very difficult to find in the conditions of modern limited monitoring; - in case of lack of above data, the method may have a significant error.
Index-rating	Foreign: Aller et al. in the USA, Canada and South Africa [17], I. S. Zektser and others in Italy, M. Civita and others in Italy [19], S. Foster for Great Britain conditions, A. Zaporozec within the state of Wisconsin, USA. Ukrainian: T. V. Yemchuk within Chernivtsi region, Ukraine [2].	- Promptness in assessing the groundwater pollution danger; - versatility of methods, which is manifested in the possibility of choosing ecological and hydrogeological parameters that are necessary precisely for the given hydrogeological conditions of research region; - the methods make it possible to take into account the lithologic-filtration factor of vulnerability (protection), as well as changes in the intensity of technogenic pressure on the geological environment of studied territory; - clarity and ease of use in presence of powerful GIS systems.	- The presence of a significant subjective factor in determining rating scales of assessment; - as a consequence of the previous one – the methods may have a significant error.
Parametric	Ukrainian: V. M. Goldberg [1], V. S. Pashkovskyi [9], O. E. Koshliakov [3], O. A. Ostroukh [8], L. M. Rogachevska [11], O. V Shcherbak [16], V. A. Myronenko, K. E. Pitieva and others. Foreign: AVI method [21].	- Versatility and adaptability to different geological and hydrogeological conditions of territory.	- The methods do not sufficiently take into account the intensity of technogenesis of territory and its changes; - sufficiently weak consideration of lithological and filtration factor of assessment, namely, filtration differences across the territory; - as a result of previous disadvantages, there may be a significant error in the methods.
Methods using modeling	Foreign: R. Zhang [22], K. Loag and others. Ukrainian: V. M. Shestopalov and others [15], O. A. Potapov.	- Minimal error, which is ensured by the use of significant volume of ecological and hydrogeological information and powerful GIS systems; - taking into account the lithology-filtration factor of vulnerability assessment; - the flexibility of assessment, which is associated with the lack of binding to a specific territory, as well as greater reliability of the forecast when taking into account the intensity of man-made pressure and its changes.	- When assessing within significant territories, methods become overloaded with large volume of ecological and hydrogeological information and become quite time-consuming and costly; - currently, the problem for all of Ukraine is lack of sufficient amount of up-to-date ecological and hydrogeological information and its operative processing. Therefore, another disadvantage is difficulty, and in some cases, impossibility of finding the necessary volume of data for research; - as a result of previous disadvantages – such important factors as the efficiency of assessment and the speed of making management decisions based on them are lost.

genesis (1960-2020) were investigated. In the process of work, the main pollutant elements of groundwater, which have systematically increased (according to DSanPiN 2.2.4-171-10) values at the investigated water intakes, were traced (Table 2). They are organized into 2 groups:

Table 2

Components of the BKA groundwater chemical composition of researched area, for which systematic exceedances of the current standards have been established

Indicator, units of measurement	Value within the territory of research	Current standard (DSanPiN 2.2.4-171-10)	City water intakes, on which systematic exceedances of current standards are established
Surface genesis			
NH_4^+, mg/dm^3	0,0-2,1	≤ 0,5	Poltava, Khorol, Krasnograd
NO_2^-, mg/dm^3	0,0-2,0	≤ 0,1	Poltava, Khorol, Krasnograd
Deep genesis			
Mineralization, mg/dm^3	260,0-5400,0	≤ 1000	Karlivka, Poltava, Kotelva, Shyshaky, Lokhvytsa, Myrhorod, Khorol, Lubny, Velyka Bagachka, Reshetylivka, Chutove, Krasnograd, Bogoduhiv
Cl^-, mg/dm^3	31,2-1110,0	≤ 250	Poltava, Karlivka, Kotelva, Lokhvytsa, Myrhorod, Khorol, Lubny, Velyka Bagachka, Reshetylivka, Chutove, Krasnograd
Fe_{total}, mg/dm^3	0,0-5,4	≤ 0,2	Karlivka, Poltava, Dykanka, Opishnya, Reshetylivka, Zinkiv, Gadyach, Lohvytsia, Khorol, Lubny, Pyryatyn, Chornuhy, Chutove, Krasnograd, Bogoduhiv
Na^++K^+, mg/dm^3	25,6-652,3	≤ 200	Karlivka, Poltava, Myrhorod, Khorol, Lubny, Reshetylivka, Chutove, Gadyach, Krasnograd
F^-, mg/dm^3	0,2-7,4	≤ 1,5	Karlivka, Poltava, Dykanka, Kotelva, Reshetylivka, Khorol, Shyshaky, Myrhorod, Lubny, Pyryatyn, Chornuhy, Velyka Bagachka, Chutove, Krasnograd, Bogoduhiv
Br^-+B^{3+}+J^- (total), mg/dm^3	0,0-3,0	≤ 0,55	Karlivka, Poltava, Dykanka, Kotelva, Reshetylivka, Gadyach, Myrhorod, Khorol, Lubny, Pyryatyn, Krasnograd
Mixed genesis			
pH, units	6,6-9,2	6,5-8,5	Poltava, Krasnograd
Si, mg/dm^3	2,0-18,7	≤ 10	Poltava, Krasnograd

- elements-pollutants of surface genesis (NH_4^+, NO_2^-), which are not characterized by a wide distribution (detected only at 3 large water intakes, such as Poltava, Khorol, Krasnograd);

- pollutant elements of deep genesis (Cl^-, Na^++K^+, F^-, $Fe_{заг.}$, Br^-, B^{3+}, J^-, as a result – increased mineralization of waters). It was established that these pollutants are the predominant factor in the deterioration of the target groundwater quality, as they were detected at most of large water intakes in the study region (Poltava, Karlivka, Kotelva, Dykanka, Opishnya, Zinkiv, Gadyach, Pyriatyn, Chornukhy, Shyshaky, Lohvytsia, Myrhorod, Khorol, Lubny, Velyka Bagachka, Reshetylivka, Chutove, Krasnograd, Bogoduhiv and some other less powerful).

According to the papers of various researchers [7, 10, 12, 13], the increased content of Cl^-, F^-, $Fe_{заг.}$, Br^-, B^{3+}, J^- in drinking water has a colossal effect on the human body. This can be expressed in a number of serious diseases of the population that systematically consumes this water, namely: endemic fluorosis, hypoplasia of tooth enamel, caries, diseases of the circulatory system, problems with the secretory activity of digestive system, chronic digestive problems, a negative effect on the permeability of cell membranes and many others.

The above-mentioned groundwater pollution occurs as a result of influence of a whole complex of factors. One of the key factors is the local insufficient natural protection of target aquifer waters from man-

made and natural pollution factors. Therefore, the authors faced the task of creating an effective and rational approach to predicting changes in the ecological state of groundwater at the water intakes operating BKA of this territory, in modern natural and man-made conditions. For this, it was necessary to identify areas where groundwater is vulnerable to technogenic and natural factors of pollution.

At the first stage, the territory was zoned according to the risk of quality deterioration of target groundwater by man-made pollutants that enter these waters in the process of downward vertical filtration and migration from the surface of the earth. The following ecological and hydrogeological indicators were studied:

1) the intensity of technogenic pressure on the geological environment and its changes within the territory;

2) the nature of complex barrier function of the upper part of GE, which is determined by the lithologic-filtering protective capacity of sediments that lie between the earth's surface and target water-bearing aquifer, into which filtering of contaminated surface water is possible;

3) the filtration parameter through a regional separate layer of poorly permeable sediments of kyiv age, which lies in the top of target aquifer.

The general distribution of indicators for assessing the protection (vulnerability) of groundwater from surface pollution and the weight of each of them are shown in Table 3. After determining all the assessment components, the obtained points were calculated for each block of territory using GIS tools. The prevalence of vulnerability categories for hydrodynamic conditions in 2020 was calculated (Table 4). The resulting map-scheme of groundwater vulnerability categories for hydrodynamic conditions in 2020 was also constructed (Fig. 1), which clearly shows the distribution of these categories.

About 25% of the research area is occupied by areas within which there is a danger of quality deterioration of BKA groundwater due to polluting elements of surface genesis. These are the southern and, partly, the western parts of territory, which include the water intakes of Poltava, Lubny, Myrhorod, Velyka Bagachka, Krasnograd, Lokhvytsia cities and some others. Along with the low geological protection of these territories, the reason for this is also the dynamic component of the protection assessment – the intensity of filtration through a separate layer of poorly permeable sediments of kyiv age, which lies in the top of target aquifer. The obtained gradations of change in the current (as of 2020) rate of vertical filtration within the studied area are quite wide and vary (not including areas of upflow) from 0 to 1460 mm/year. This is due to the presence of operating water intakes in the area of Poltava city, as well as the largest cities of region (Myrhorod, Lubny, Krasnograd, Lokhvytsia and some others), which actively exploit the target buchak-kaniv and lower-lying cenomanian-Lower Cretaceous aquifers and form depression funnels with significant components of downward migration into the target aquifer [6].

Table 4

Prevalence of categories of BKA groundwater vulnerability to surface pollution in the central part of DDAB for hydrodynamic conditions in 2020

Groundwater vulnerability category	Prevalence, % of the total area
low	75
middle	16
high	9

At the second stage, the territory was zoned according to the danger of quality deterioration of BKA groundwater due to the upward migration of natural deep substandard waters. The authors established that the maximum changes in the BKA waters composition are characteristic for the areas of "overlap" of zones of intensive man-made pressure on ground-water (zones of powerful water intakes influence) on the territory, in the subsoil section of which salt diapirs and related tectonic faults lie. It is here that the aquifers of active water exchange zone are fed by hydraulic connection with deep, highly mineralized waters [14].

The following ecological and hydrogeological indicators were studied:

1) influence of natural neotectonic factors on the target aquifer groundwater quality. The size of territory, within which the maximum deterioration of BKA groundwater quality, was observed. These are areas within a radius of 5 km around tectonic faults. Having analyzed all similar cases within the research region, the territory was conditionally divided into blocks of equal size – 5x5 km;

2) modern geodynamic activity of the earth's crust within the region. The authors believe that this parameter has an influence on the hydrogeomigratory processes through tectonic faults. The indicator was calculated by using study of total amplitudes of the earth's crust Neogene-Quaternary movements within the researched territory.

Fig. 2 shows a map-scheme of intensity of the earth's crust modern movements as a factor affecting

Table 3

General distribution of indicators for groundwater protection assessing from surface pollution

No.	Indicator name	Parameter to be defined and unit of measurement	Interval of values	Indicator of protection category, points	Weight factor
1	Lithology of the upper (near-surface) part of section	Determination of characteristic lithological composition of sediments of the section upper part according to typical areas	Areas of the 1st type	1	1,5
			Areas of the 2nd type	2	
			Areas of the 3rd type	5	
2	Inherent geological protection of the first interlayer aquifer	Specific permeability of poorly permeable rocks in the top and directly in the first interlayer aquifer, day^{-1}	$>6,7x10^{-5}$	1	5
			$6,7x10^{-5} – 5x10^{-5}$	2	
			$5x10^{-5} – 3,3x10^{-5}$	3	
			$3,3x10^{-5} – 2,5x10^{-5}$	4	
			$<2,5x10^{-5}$	5	
3	Permeability of sediments of the first interlayer aquifer	Specific permeability of permeable rocks in the first interlayer aquifer, day^{-1}	>0,3	1	1,5
			0,3-0,15	2	
			0,15-0,1	3	
			0,1-0,075	4	
			<0,075	5	
4	Permeability of the separating layer	Specific permeability of the regional separate layer of poorly permeable rocks, which lies in the top of target aquifer, day^{-1}	$>5x10^{-6}$	1	10
			$5x10^{-6} – 4x10^{-6}$	2	
			$4x10^{-6} – 3,3x10^{-6}$	3	
			$3,3x10^{-6} – 2,9x10^{-6}$	4	
			$<2,9x10^{-6}$	5	
5	Velocity of vertical flow through the separation layer	Velocity of vertical flow through a regional separation layer of poorly permeable rocks in the top of target aquifer, m/day	$>10^{-4}$	1	10
			$10^{-4} – 5x10^{-5}$	2	
			$5x10^{-5} – 10^{-5}$	3	
			$10^{-5} – 10^{-7}$	4	
			$10^{-7} – 0$	5	
			<0	Conditionally protected from surface contamination	

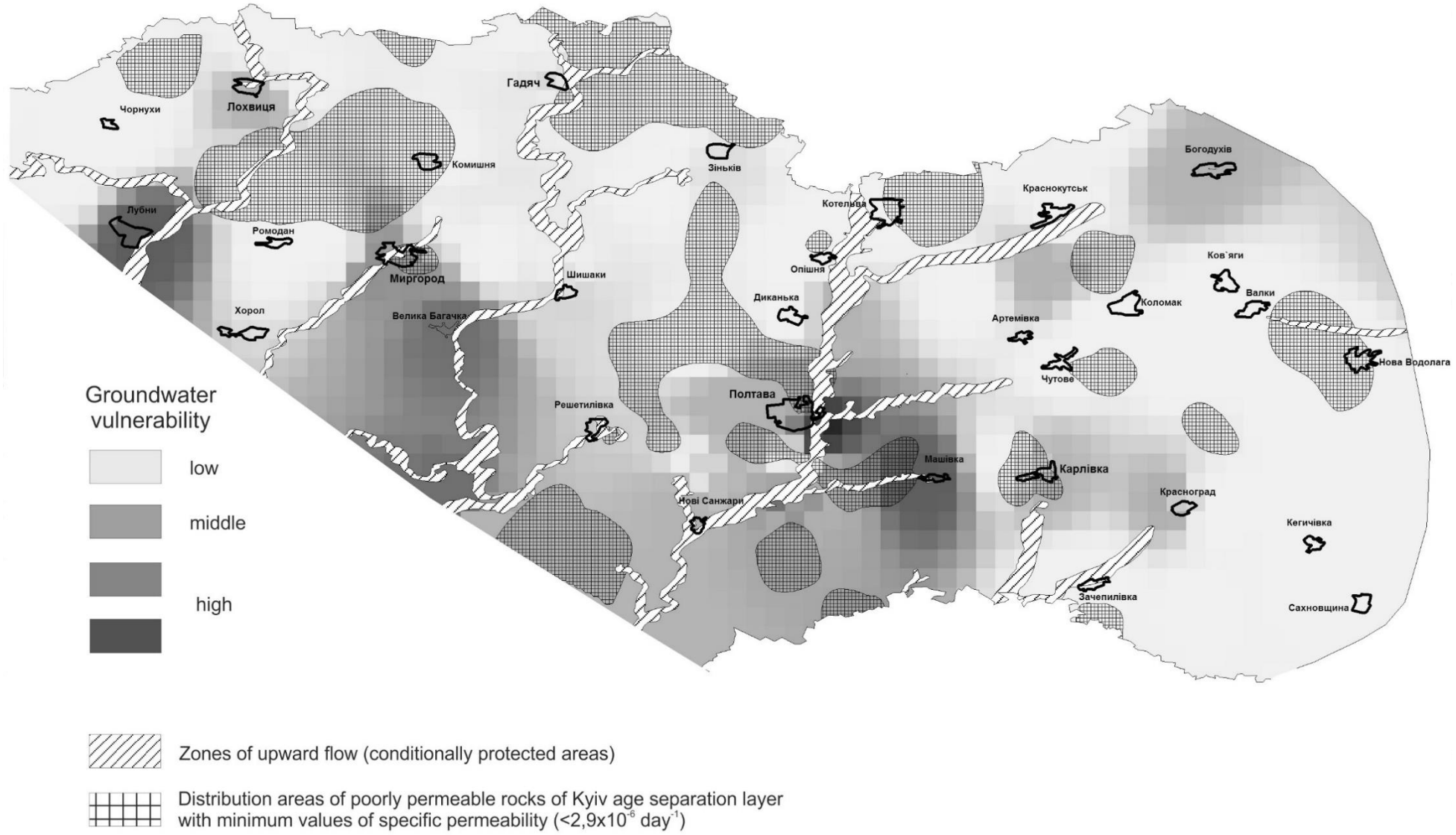

Fig. 1. Map-scheme of categories of BKA groundwater vulnerability to surface pollution in the central part of DDAB for hydrodynamic conditions in 2020

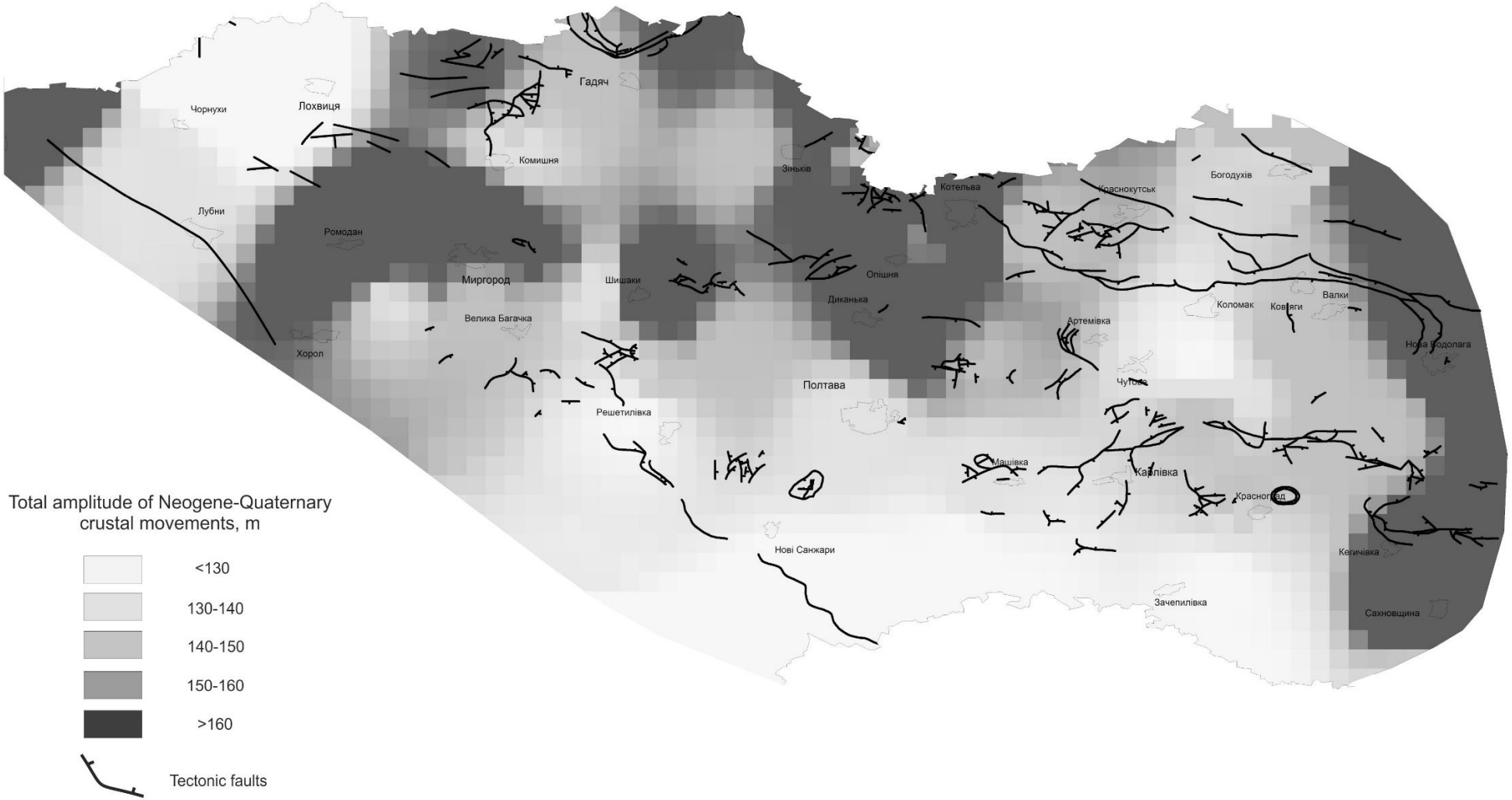

Fig. 2. Map-scheme of intensity of the earth's crust modern movements as a factor affecting the vulnerability (protection) of BKA groundwater to natural neotectonic factors of its quality reduction in the central part of DDAB due to the permeability of tectonic faults

the vulnerability (protection) of BKA groundwater to natural neotectonic factors of its quality reduction in the central part of DDAB due to the permeability of tectonic faults.

With the help of a rational integration of all the above factors, the zones of increased ecological danger of quality reduction of BKA drinking groundwater due to elements of deep genesis have been determined. These are the northern, central and eastern parts of the territory, which include the water intakes of Poltava, Lubny, Myrhorod, Shyshaky, Opishnia, Gadyach, Krasnograd, Karlivka cities and some others.

Conclusions. The article is a continuation of the authors' previous papers on improving the methodical approach to assessing the vulnerability (protection) of drinking groundwater within the Dnipro-Donetsk artesian basin and is a practical component of these studies.

Complex zoning systems of the territory of DDAB central part have been developed according to the degree of ecological danger of lowering the drinking groundwater quality of buchak-kaniv aquifer, which is one of the strategic reserves of drinking water within the Eastern Ukraine. It has been established that this is an effective tool for forecasting changes in the ecological state of groundwater at water intakes in the researched area under modern natural and technogenic conditions.

Zones of increased ecological danger of the quality reduction for BKA drinking groundwater due to elements of the surface (southern and, partly, the western parts of territory – water intakes of Poltava, Lubny, Myrhorod, Velyka Bagachka, Krasnograd cities and some others) and deep (northern, central, eastern parts – water intakes of Poltava, Romodan, Myrhorod, Shyshaky, Opishnia, Gadyach, Krasnograd, Karlivka cities and some others) genesis were established.

It is recommended to develop measures within these territories to increase the ecological safety of the population's drinking water supply. This is, first of all, hydrogeochemical monitoring of characteristic indicators of the water qualitative composition and optimization of operating modes for powerful water intakes. Within the territories with a potentially lower risk of groundwater quality deterioration, it is recommended to create new water intakes to gradually replace the current population's water supply of urban agglomerations with high-quality groundwater.

Bibliography

1. *Гольдберг В. М. Природные и техногенные факторы защищенности грунтовых вод / В. М. Гольдберг // Бюллетень МОИП. – 1983. – № 2. – С. 103–110.*
2. *Ємчук Т. В. Оцінка захищеності підземних вод: методологічні аспекти і практичне застосування вод / Т. В. Ємчук // Гідрологія, гідрохімія і гідроекологія. – 2011. – Т. 1. № 22. – С. 45–50.*
3. *Кошляков О. Є. До питання вразливості питних підземних вод в межах Київської міської агломерації з урахуванням природної захищеності / О. Є. Кошляков, О. В. Диняк, І. Є. Кошлякова // Вісник Одеського національного університету. Серія «Географічні та геологічні науки». – 2014. – Т. 19. № 3 (22). – С. 269–273.*
4. *Левонюк С. М. Геоекологічні критерії удосконалення методики оцінки ризику забруднення підземних вод / С. М. Левонюк, І. В. Удалов // Екологічна безпека: проблеми і шляхи вирішення : матеріали XIV Міжнародної науково-практичної конференції, 10-14 вересня 2018 р., Харків, 2018. – С. 203–208.*
5. *Левонюк С. М. Еколого-гідрохімічні особливості трансформації якості питних підземних вод під впливом техногенних та неотектонічних факторів (на прикладі бучацько-канівських водозаборів Східної України) / С. М. Левонюк, І. В. Удалов // Пошукова та екологічна геохімія. – 2018. – № 1 (19). – С. 30–40.*
6. *Левонюк С. М. Комплексна геоекологічна оцінка захищеності питних підземних вод / С. М. Левонюк, І. В. Удалов // Вісник Одеського національного університету. Серія «Географічні та геологічні науки». – 2018. – Т. 23, вип. 2 (33). – С. 111–133.*
7. *Назаренко Е. А. Оцінка стану здоров'я населення, що проживає в межах території біогеохімічної провінції з підвищеним вмістом фторидів / Е. А. Назаренко, Ю. Б. Нікозять, О. Д. Іващенко // Науково-технічний журнал. – 2015. – № 2 (12). – С. 80–84.*
8. *Остроух О. А. Якісна оцінка природної захищеності підземних вод засобами ГІС / О. А. Остроух // Вісник Харківського національного університету імені В. Н. Каразіна. Серія «Геологія. Географія. Екологія». – 2013. – Вип. 38. № 1049. – С. 34–38.*
9. *Пашковский И. С. Принципы оценки защищенности подземных вод от загрязнения / И. С. Пашковский // Современные проблемы гидрогеологии и гидромеханики. – 2002. – С. 122–131.*
10. *Попов О. И. Воздействие фтора и его производных на окружающую среду и организм человека / О. И. Попов, Л. В. Подригало, Г. Н. Даниленко, Н. Г. Семко // Врачебная практика. – 2000. – № 1. – С. 87–89.*
11. *Рогачевская Л. М. Региональная оценка уязвимости грунтовых вод восточной части Днепровского артезианского бассейна к радионуклидному загрязнению : автореф. дисс. канд. геол.-мин. наук / Л. М. Рогачевская. – Москва, 2002. – 23 с.*
12. *Сердюкова О. О. Гідрогеохімічні особливості фтора у зоні гіпергенезу Донбасу та деякі аспекти його впливу на організм людини / О. О. Сердюкова // Вісник Харківського національного університету імені В. Н. Каразіна. Серія «Геологія. Географія. Екологія». – 2013. – № 1084. – С. 243–246.*

13. Смоляр В. І. Надлишок фтору в питній воді і фтористa інтоксикація / В. І. Смоляр, Г. І. Петрашенко // Проблеми харчування. – 2007. – № 1. – С. 15–17.
14. Удалов І. В. Трансформація якісного складу питних підземних вод центральної частини ДДАБ / І. В. Удалов, С. М. Левонюк // Геохімія техногенезу. – 2019. – Вип. 2 (30). – С. 46–55.
15. Шестопалов В. М. Оценка защищенности и уязвимости подземных вод с учетом зон быстрой миграции / В. М. Шестопалов, А. С. Богуславский, В. Н. Бублясь. – Киев : Ин-т геол. наук НАН Украины, 2007. – 120 с.
16. Щербак О. В. Зміна природної захищеності підземних вод в умовах підтоплення на території Херсонської області / О. В. Щербак // Вісник Одеського національного університету. Серія «Географічні та геологічні науки». – 2013. – Т. 18, вип. 1 (17). – С. 249–253.
17. Aller L. DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings / L. Aller, T. Bennet, J. H. Lehr, R. Petty. – Washington : U. S. Environmental Protection Agency. 1987. – EPA/600/2-85-018.
18. Ball D. Development of a groundwater vulnerability screening methodology for the Water Framework Directive. Final report. Project WFD28 / D. Ball, A. MacDonald, B. Dochartaigh, M. del Rio. – Edinburgh : SNIFFER, 2004. – 52 p.
19. Civita M. Assessing and mapping groundwater vulnerability to contamination: The Italian «combined» approach / M. Civita, M. De Maio // Geofisica Internacional. – 2004. – Vol. 43, № 4. – P. 513–532.
20. Sililo O. T. N. A procedure for deriving qualitative contaminant attenuation maps from land type data / O. T. N. Sililo, J. E. Conrad, T. E. Dohse, G. Tredoux // Journal of Hydrology. – 2001. – Vol. 241. – P. 104–109. https://doi.org/10.1016/S0022-1694(00)00375-9
21. Van Stempvoort D. A method for groundwater protection mapping in the Praire Province of Canada. PPWB Report No. 114 / D. Van Stempvoort, L. Ewert, L. Wassenaar. – Saskatoon, Saskatchevan : National Hydrogeology Research Institute, 1995. – 145 p.
22. Zhang R. Determination of nonpoint-source pollution using GIS and numerical models / R. Zhang, J. D. Hamerlinck, S. P. Gloss, L. Munn // Journal of Environmental Quality. – 1996. – Vol. 25 (3). – P. 411–418. https://doi.org/10.2134/jeq1996.00472425002500030005x

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References

1. Goldberg, V. M. (1983). Natural and technogenic factors of groundwater protection. Bulletin MOIP. № 2, 103–110. [in Russian].
2. Yemchuk, T. V. (2011). Assessment of groundwater protection: methodological aspects and practical application. Hydrology, hydrochemistry and hydroecology. Iss. 1, № 22, 45–50. [in Ukrainian].
3. Koshliakov, O. Ye., Dyniak, O. V., Koshliakova, I. Ye. (2014). To the question of vulnerability of drinking groundwater within the boundaries of Kyiv city agglomeration, taking into account natural protection. Bulletin of Odessa National University. Series "Geographical and geological sciences". Iss. 19, № 3 (22), 269–273. [in Ukrainian].
4. Levoniuk, S. M., Udalov, I. V. (2018). Geoecological criteria for improving the methodology for assessing the risk of groundwater pollution. Environmental safety: problems and solutions : materials of XIV International Scientific and Practical Conference. Kharkiv, Ukraine, 203–208. [in Ukrainian].
5. Levoniuk, S. M., Udalov, I. V. (2018). Ecological and hydrochemical features of the transformation of drinking groundwater quality under the influence of technogenic and neotectonic factors (on the example of buchak-kaniv water intakes of Eastern Ukraine. Research and environmental geochemistry. № 1 (19), 30–40. [in Ukrainian].
6. Levoniuk, S. M., Udalov, I. V. (2018). Comprehensive geoecological assessment of drinking groundwater protection. Bulletin of Odessa National University. Series "Geographical and geological sciences". Iss. 2 (33), 111–133. [in Ukrainian].
7. Nazarenko, E. A., Nikoziat, Yu. B., Ivashchenko, O. D. (2015). Assessment of health state of population living within the territory of biogeochemical province with high fluoride content. Scientific and technical journal. Kyiv. 2 (12). 80–84. [in Ukrainian]
8. Ostroukh, O. A. (2013). Qualitative assessment of the groundwater natural protection by using GIS. Bulletin of V. N. Karazin Kharkiv National University. Series "Geology. Geography. Ecology". Iss. 38, № 1049, 34–38. [in Ukrainian].
9. Pashkovskyi, I. S. (2002). Principles for assessing the groundwater protection from pollution. Modern problems of hydrogeology and hydromechanics. 1, 122–131. [in Russian].
10. Popov, O. I., Podryhalo, L. V., Danylenko, H. N., Semko, N. H. (2000). The impact of fluorine and its derivatives on the environment and the human body. Medical practice. Kyiv. 1. 87–89. [in Russian]
11. Rogachevskaya, L. M. (2002). Regional assessment of vulnerability of groundwater in the eastern part of Dnipro artesian basin to radionuclide contamination : PhD thesis. Moscow, 23. [in Russian].
12. Serdiukova, O. O. (2013). Hydrogeochemical features of fluorine in the hypergenesis zone of Donbas and some aspects of its influence on the human body. Bulletin of V. N. Karazin Kharkiv National University. The series "Geology. Geography. Ecology". Kharkiv. 1084. 243–246. [in Ukrainian]
13. Smoliar, V. I., Petrashenko, H. I. (2007). Excess fluoride in drinking water and fluoride intoxication. Nutritional problems. Kyiv. 1. 15–17. [in Ukrainian]

14. *Udalov, I. V., Levoniuk, S. M. (2019). Transformation of the qualitative composition of drinking groundwater in the central part of DDAB. Geochemistry of technogenesis. Iss. 2 (30), 46–55. [in Ukrainian].*
15. *Shestopalov, V. M., Boguslavskyi, A. S., Bublias, V. N. (2007). Assessment of the protection and vulnerability of groundwater, taking into account the zones of rapid migration. Kyiv, 120. [in Russian].*
16. *Shcherbak, O. V. (2013). Changes in the groundwater natural protection in conditions of flooding in the territory of Kherson region. Bulletin of Odessa National University. Series "Geographical and geological sciences". Iss. 18, № 1 (17), 249–253. [in Ukrainian].*
17. *Aller, L., Bennet, T., Lehr, J. H., Petty, R. (1987). DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings. Washington: U. S. Environmental Protection Agency. EPA/600/2-85-018.*
18. *Ball, D., MacDonald, A., Dochartaigh, B., del Rio, M. (2004). Development of a groundwater vulnerability screening methodology for the Water Framework Directive. Final report. Project WFD28. Edinburgh: SNIFFER, 52.*
19. *Civita, M., De Maio, M. (2004). Assessing and mapping groundwater vulnerability to contamination: The Italian «combined» approach. Geofisica Internacional. Vol. 43, № 4, 513–532.*
20. *Sililo, O. T. N., Conrad, J. E., Dohse, T. E., Tredoux, G. (2001). A procedure for deriving qualitative contaminant attenuation maps from land type data. Journal of Hydrology. Vol. 241, 104–109. https://doi.org/10.1016/S0022-1694(00)00375-9*
21. *Van Stempvoort, D., Ewert, L., Wassenaar, L. (1995). A method for groundwater protection mapping in the Praire Province of Canada. PPWB Report No. 114. Saskatoon, Saskatchevan: National Hydrogeology Research Institute, 145.*
22. *Zhang, R., Hamerlinck, J. D., Gloss, S. P., Munn, L. (1996). Determination of nonpoint-source pollution using GIS and numerical models. Journal of Environmental Quality. Vol. 25 (3), 411–418. https://doi.org/10.2134/jeq1996.00472425002500030005x.*

Оцінка вразливості питних підземних вод бучацько-канівського водоносного комплексу в умовах довгострокової трансформації їх якісного складу

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Дана робота є продовженням попередніх публікацій авторів з удосконалення методичного підходу до оцінки вразливості (захищеності) питних підземних вод у межах Дніпровсько-Донецького артезіанського басейну (ДДАБ) та є практичною складовою цих досліджень. Задля пошуку та розробки оптимальних форм управління екологічною безпекою питного водопостачання населення регіону, апробовано удосконалений авторами підхід до оцінки вразливості (захищеності) питних підземних вод на стратегічно важливих водах бучацько-канівського водоносного комплексу (БКВК). Розроблено комплексні системи еколого-гідрогеологічного районування території центральної частини ДДАБ за ступенем екологічної небезпеки зниження якості питних підземних вод БКВК. Проведено районування території згідно небезпеки погіршення якості цих вод техногенними забруднювачами, які надходять у води у процесі низхідної вертикальної фільтрації та міграції із поверхні землі. Встановлено екологічно небезпечні території із потенційним зниженням якості питних підземних вод БКВК за рахунок елементів поверхневого генезису (водозабори міст Полтава, Лубни, Миргород, Велика Багачка, Красноград та деякі ін.). Проведено районування території згідно небезпеки погіршення якості підземних вод БКВК за рахунок висхідної міграції природних глибинних некондиційних вод. Встановлено екологічно небезпечні території із потенційним зниженням якості підземних вод за рахунок елементів глибинного генезису (водозабори міст Полтава, Ромодан, Миргород, Шишаки, Опішня, Гадяч, Красноград, Карлівка та деякі ін.). Практично доведено, що удосконалений авторами підхід до оцінки вразливості (захищеності) питних підземних вод є ефективним інструментом для прогнозування змін екологічного стану підземних вод на водозаборах території робіт у сучасних природних і техногенних умовах.

Ключові слова*: підземні води, вразливість, захищеність, методичний підхід, погіршення якості, екологічна безпека.*

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