UDC 556.388

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GROUNDWATER AND ITS SUSCEPTIBILITY TO CONTAMINATION IN KHERSON REGION

(Reviewed by the editorial board member O. Koshliakov)

Goal. The goal of the research is zoning of Kherson region on the basis of the upper Miocene water-bearing complex sensitivity to contamination caused by potentially dangerous types of economic activity.

Research methods. The methodical approach to determining the sensitivity of groundwater to contamination based on sensitivity index was proposed. For these purpose the index-rating, parametric methods, method of zoning and geoinformational (GIS) approach were used.

Research results. This study evaluated the sensitivity of the upper Miocene aquifer complex to contamination in Kherson region. The groundwater sensitive to pollution is mostly in the areas closest to the rivers (Dniper, Ingylets), where natural protection of groundwater is low, and in urban areas with a great number of anthropogenic objects.

Originality. For the first time, the quantitative criterion has been developed to assess anthropogenic load on the underground hydrosphere. Based on this criterion, a consistent approach to the assessment of groundwater vulnerability to pollution in the Kherson region was proposed. Such approach takes into account not only the static factors of groundwater protection, but also its dynamic component – anthropogenic loads, hydrogeodynamic conditions.

Practical application of the research. The potentially dangerous territories were allocated, in terms of pollution of the upper Miocene water-bearing complex – the main source of potable groundwater. This zoning is an important step in planning the location of monitoring, water supply wells and dangerous anthopogenic objects. The methodological approaches and techniques can be used to study groundwater in other areas.

Introduction. Groundwater is an important source of water to supply human needs. In the last few years, there has been a tendency for drinking groundwater quality to deteriorate, which resulted in increasing anthropogenic impact on the environment. The protection of groundwater quality from the impact of human activities is a high priority because:

- groundwater moves slowly through the ground and so the impact of human activities lasts for a relatively long time;
- groundwater may be difficult to clean up, even when the source of pollution is removed;
- groundwater provides baseflow to surface water systems and accordingly its quality influences the recreational value of surface water and its potential use for water supply purposes;
- unlike surface water where flow is in defined channels, groundwater is present everywhere.

The groundwater sensitivity to pollution schemes should be used by land-use planners and water resources managers for the most practical and effective means of protecting groundwater and preventing pollution. The scheme consists of two closely interlinked components: groundwater protection and potentially groundwater pollution activities.

This study presents the methodological approach to build digital map of groundwater sensitivity to pollution in Kherson region. This is because, Kherson region is one of the most problematic regions of Ukraine, from the point of view of the present state and maintains the trend of drinking groundwater quality deterioration.

Kherson region is located in the south of Ukraine, in the area of insufficient moisture. One of the major ecological problem of the region is the shortage of fresh groundwater. This problem reveals causal relationship between the irrigation practice, aquifer overexploitation and a complex of natural conditions.

The main source of drinking water is the upper Miocene (the main Neogene) water-bearing complex, widespread in Kherson region. Under the influence of natural and anthropogenic factors, the groundwater quality deteriorates over time. Thus, the regional process of increasing of the water salinity, total hardness, phenol and nitrate contamination and local pollution by Ba, Li, Se of groundwater were fixed in the years 2006-2009, during the testing of groundwater withdrawals [2].

The study has produced a map of sensitivity to pollution of the upper Miocene aquifer complex in Kherson region which will be useful to policy makers for scheduling of dangerous anthropogenic objects and new water supply wells in order to maintain the quality of drinking groundwater. It is for these reasons that the study has derived its relevance.

Methodology. Index-rating, parametric methods, method of zoning and geoinformational (GIS) approach were used in research. Schematically, the algorithm of mapping of sensitivity groundwater to pollution is illustrated in Figure 1.

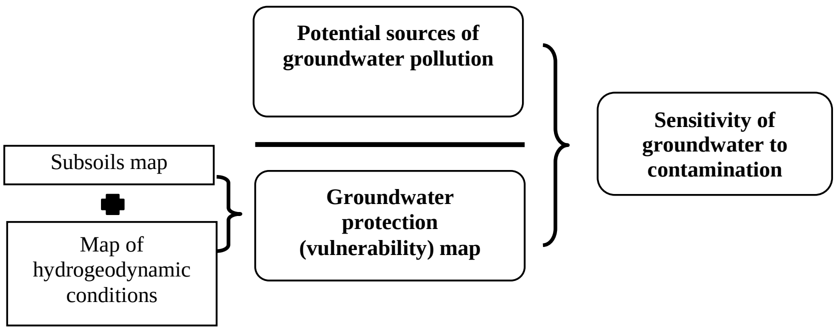

Figure 1. Conceptual framework for production a map of sensitivity groundwater to contamination

The first stage of the work is the creation of information layers maps, accompanied by attribute tables (database). The ArcView GIS package was used to digitize a groundwater protection map and other relevant themes of the study area. The following information layers were created:

1. Local potential sources of groundwater pollution (field of filtration, gas stations, sedimentation tanks, cattle

cemetery, farm, storage of fertilizers, pesticides, toxic chemicals, waste dump);

2. Natural protection map of the upper Miocene aquifer complex;

3. Hydrodynamic conditions map, with different hydrodynamic ratio of the first surface aquifer and the upper Miocene aquifer complex.

The input data for informational layers were collected from the published map – "Level of changes in forming of the main upper Miocene aquifers zoning map", scale 1:200 000 (A. Luschyk, 2010) [2].

At the second stage of the work, the index-rating method was applied. For each object in the database a quantitative assessment has been given in terms of its impact on groundwater. The degree of possible impacts of anthropogenic objects on the groundwater in these natural and man-made conditions was estimated by the hazard index – the ratio of the amount of experimentally detected toxic elements in groundwater to their theoretical predictions (by A. Luschyk, [2]). Hazard index values vary in the range of 0 to 1, respectively, anthropogenic objects, with a value of hazard index which equals one, have had the greatest negative impact on groundwater (waste dump, storage of liquid waste).

The degree of natural protection of the upper Miocene aquifer complex was estimated by the methodological approach developed by VSEGINGEO. Thus, the natural protection of groundwater depends on geological factors – composition and thickness of subsoils. In other words, the subsoils (sands, gravels, glacial tills (or boulder clays), peat, lake and alluvial silts and clays), are the single most important natural feature influencing groundwater vulnerability and groundwater contamination prevention. Groundwater is mostly at risk where the subsoils are absent or thin and, in the areas of karstic limestone, where surface streams sink underground at swallow holes. Three groundwater natural protection categories are used in the map – protected, conditionally protected and unprotected. All polygons with different degrees of natural protection of groundwater were estimated by respective points – 3 points (protected area), 2 points (conditionally protected), 1 points (unprotected). Geological factors that determine the natural protection of groundwater are constant over time.

The protection of groundwater depends on hydrogeological condition too, in particular on hydrogeodynamics of the adjacent aquifers. Hydrogeodynamics conditions determine the velocity and the direction of seepage of infiltrated water (and contaminants). But this is a variable factor of the groundwater protection. In this research the present state of the hydrogeodynamic conditions of the upper Miocene aquifer complex were analyzed. Polygons with different degrees of hydrogeodynamic conditions of the upper Miocene aquifer complex were estimated by points too – 3 points (protected area), 2 points (conditionally protected), 1 points (unprotected). The upper Miocene aquifer complex is protected in areas where the level of the surficial aquifer is located below the level of the upper Miocene. Thus, the contaminated water of the surficial aquifer can't seep into the deeper aquifers. The conditionally protected areas are where the level of the surficial aquifer is located above the level of the upper Miocene aquifer complex on 0-10 m. The unprotected areas are where the level of the surficial aquifer is located more than 10 m above the level of the upper Miocene aquifer complex. Namely, under such pressure differences the water seepage through the clay strata begins.

The parametric method was used at the third stage of research. To characterize the interaction between the groundwater and the environment pollution the sensitivity index was used, proposed by V. Goldberg in 1987 and modified by the author. According to V. Goldberg, the sensitivity index (P) is the ratio of anthropogenic load module (m) to the protection of groundwater index (S), expressed in points. Thus, the sensitivity of groundwater to contamination is directly proportional to anthropogenic impact on the underground hydrosphere and inversely proportional to the protection of groundwater [1]. Special quantitative criterion (total hazard index) was proposed by the author, to identify the anthropogenic load on the underground hydrosphere [3]. Based on total hazard index the sensitivity index was calculated according to the following equation:

$$P = \frac{\sum K_h / F}{\left(S_n + S_g\right)}, \qquad (1)$$

were P – sensitivity index; $\sum K_h$ – total hazard index (sum of hazard indexes of each local potential source of groundwater pollution, located on the unit area); F – area, km^2; S_n – natural protection of groundwater, in points; S_g – protection of groundwater that depends on hydrogeodynamic conditions, in points. For areas with similar conditions of protection of the upper Miocene aquifer complex the sensitivity index was calculated.

At the last stage of the work, the map of sensitivity of the upper Miocene aquifer complex to contamination was prepared (Figure 2) using the sensitivity index.

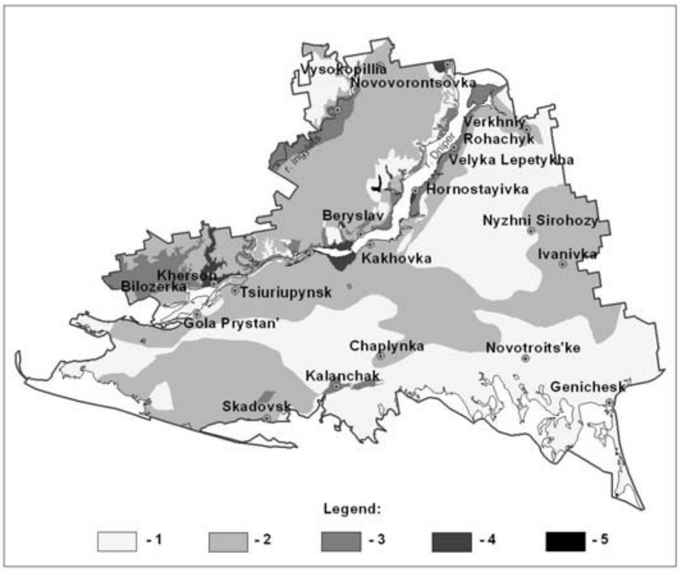

Figure 2. Scheme of sensitivity of the upper Miocene aquifer complex to contamination in Kherson region:
1 – P=0; 2 – P=0-0,01; 3 – P=0,01-0,03; 4 – P=0,03-0,08; 5 – P=0,08-0,12

The impact of anthropogenic objects on the groundwater and the other themes within the protection of groundwater were assessed using GIS overlay manipulations. As a result, five classes of groundwater sensitivity to pollution were identified in Kherson region. The method of the natural breakdown in ArcView GIS was used to separate the classes. These classes are as follows:

1. Areas marked as not susceptible to pollution (P=0);
2. Areas marked as badly susceptible to pollution (P=0-0,01);
3. Areas marked as potentially susceptible to pollution (P=0,01-0,03);
4. Areas marked as susceptible to pollution (P=0,03-0,08);
5. Areas marked as highly susceptible to pollution (P=0,08-0,12).

As presented in Figure 2, there are variations in the degree of groundwater sensitivity to pollution in Kherson region. Significant part of Kherson region has had a low degree of sensitivity of the upper Miocene aquifer complex to contamination (1, 2 classes). The groundwater sensitive to pollution is mostly in the areas closest to the rivers (Dniper, Ingylets), where natural protection of groundwater is low, and in urban areas with a great number of anthropogenic objects.

Conclusions. In this research, an algorithm for estimation sensitivity of groundwater to contamination without additional field work was proposed. Such an approach takes into account not only the static factors of groundwater protection, but also its dynamic component – anthropogenic loads, hydrogeodynamic conditions. This study emphasises the importance of a GIS database in tackling groundwater vulnerability related problems.

The scheme of sensitivity of the upper Miocene aquifer complex to contamination in Kherson region can be applied to groundwater conditions management as part of groundwater monitoring procedure, for the planning authorities to carry out their functions, and a framework to assist in decision-making on the location, nature and control of development and activities in order to protect groundwater.

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Received by Editorial Board on 16.10.13

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ПІДЗЕМНІ ВОДИ ТА ЇХ ЧУТЛИВІСТЬ ДО ЗАБРУДНЕННЯ У ХЕРСОНСЬКІЙ ОБЛАСТІ

Мета. Метою дослідження є районування території Херсонської області за рівнем чутливості підземних вод верхньоміоценового водоносного комплексу до забруднення, спричиненого потенційно небезпечними для підземних вод видами господарської діяльності.

Методи дослідження. Запропоновано методичний підхід до визначення рівня чутливості підземних вод до забруднення, на основі кількісного критерію – індексу чутливості. В роботі застосовувались індексно-рейтингові, параметричні, методи районування та геоінформаційний підхід.

Результати дослідження. Визначено рівень чутливості підземних вод верхньоміоценового водоносного комплексу до забруднення на території Херсонської області. Так, найбільш уразливими до забруднення є території поблизу річкових долин (Дніпро, Інгулець), де низька природна захищеність водоносного горизонту та в районах міської забудови, де розміщується велика кількість техногенних об'єктів.

Наукова новизна. Вперше запропоновано кількісний критерій для оцінки антропогенного навантаження на підземну гідросферу. На основі такого критерію, розроблено методичний підхід до оцінки чутливості підземних вод до забруднення для території Херсонській області. В даному підході враховані не лише статичні фактори захищеності підземних вод, але й її динамічна складова – антропогенне навантаження, гідрогеодинамічні умови.

Практична значимість. Виділено потенційно небезпечні території з точки зору забруднення верхньоміоценового водоносного комплексу – основного джерела питних підземних вод. Таке районування території є важливим етапом при плануванні розміщення моніторингових, водозабірних свердловин, небезпечних техногенних об'єктів. Запропоновані методичні підходи та прийоми можуть бути використані для вивчення підземних вод на інших територіях.

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ПОДЗЕМНЫЕ ВОДЫ И ИХ ЧУВСТВИТЕЛЬНОСТЬ К ЗАГРЯЗНЕНИЮ В ХЕРСОНСКОЙ ОБЛАСТИ

Цель. Целью исследования является районирование территории Херсонской области по уровню чувствительности подземных вод верхньомиоценового водоносного комплекса к загрязнению, вызванного потенциально опасными для подземных вод видами хозяйственной деятельности.

Методы исследования. Предложен методический подход к определению уровня чувствительности подземных вод к загрязнению, на основе количественного критерия – индекса чувствительности. В работе применялись индексно-рейтинговые, параметрические, методы районирования и геоинформационный подход.

Результаты исследования. Определен уровень чувствительности подземных вод верхньомиоценового водоносного комплекса к загрязнению на территории Херсонской области. Так, наиболее уязвимыми к загрязнению являются территории вблизи речных долин (Днепр, Ингулец), где низкая естественная защищенность водоносного горизонта и в районах городской застройки, где сосредоточено большое количество техногенных объектов.

Научная новизна. Впервые предложен количественный критерий для оценки антропогенной нагрузки на подземную гидросферу. На основе такого критерия, разработан методический подход к оценке чувствительности подземных вод к загрязнению для территории Херсонской области. В данном подходе учтены не только статические факторы защищенности подземных вод, но и ее динамическая составляющая – антропогенная нагрузка, гидрогеодинамические условия.

Практическая значимость. Выделены потенциально опасные территории с точки зрения загрязнения верхньомиоценового водоносного комплекса – основного источника питьевых подземных вод. Такое районирование территории является важным этапом при планировании размещения мониторинговых, водозаборных скважин, опасных техногенных объектов. Предложенные методические подходы и приемы могут быть использованы для изучения подземных вод и на других территориях.