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Criteria for Assessing Groundwater Contamination Levels of Marl and Chalk Water Intakes in Eastern Ukraine

Key words: *underground waters, chalk intakes, marl-chalk aquifers, groundwater pollutants, water quality indicators.*

Annotation: *The article deals with the problem of changing the qualitative composition of underground waters of the marl-chalk aquifer in the territory of Eastern Ukraine used for domestic and drinking purposes. The main factors influencing the change in the qualitative composition of drinking groundwater of these water intakes have been characterized. Drinking groundwater has been systematized according to the level of pollution and quality.*

How to provide the population with quality drinking water is one of the basic problems for each country. Ukraine is no exception in this respect. As is known, the situation with drinking water quality is especially dramatic in the east of the country where there are large industrial and mining centers. It is noted that Eastern Ukraine is supplied with economic and drinking water through the exploitation of both surface and groundwater. The priority source of drinking water supply is the underground water of the marl and chalk aquifer (MMWG) which, in comparison with the surface waters and waters of other aquifers, is of a higher quality and has a more stable composition. Recently there has been noted persistent deterioration in the quality of these waters. There has been recorded an increase in the content of components characteristic of natural groundwater in them (chlorides, sulphates, etc.), as well as microcomponents and compounds associated exclusively with human activities (organic substances, heavy metals, radionuclides, etc.).

Numerous studies confirm that environmental pollutants in the overwhelming majority of cases are the factors listed above. According to these studies, the analyzed indicators are selected in the article. Analysis of geological, hydrogeological, tectonic features of the study area indicates that the fixation of the noted indicators in groundwater is associated with the following processes and phenomena:
– infiltration of sewage from the territory of enterprises, agricultural lands and settlements;
– lifting of highly mineralized groundwater to the water intake from deeper parts of the reservoir;

– availability of hydrogeological "windows" in the waterproof stratum through which more intensive flow occurs;
– pulling up the contaminants into the exploited aquifer with a depression funnel.

Analyzing the features of man-caused pollution of underground waters of MMWG in conditions of sewage infiltration, we have noted that the sources of man-made pollution are characterized by a variety of chemical composition. In addition, the volume is different and their inflow into groundwater in the study area is unevenly distributed. According to the annual regional environmental report in Lugansk and Kharkiv regions, the first place in terms of the amount of contaminated sewage discharged into water sources belongs to industrial and domestic sewage, and in a smaller amount, mine water discharge. This is due to the high population density and a large number of different industrial, coal mining and agricultural enterprises operating in this territory.

Chemical composition of industrial wastewater is characterized by high toxicity and is represented mainly by the following indicators: NH_4^-, NO_2, NO_3, Cl^-, H_2S, phenols, petroleum products, heavy metals complex and a number of other toxic substances. The composition of domestic wastewater is relatively more or less homogeneous, although the concentration of substances is very diverse (P_2O_5, K_2O, SO_4^{2-}, Cl^-, etc.). Special attention deserves pollution of groundwater by sewage within the agricultural areas. This pollution is associated with the intensive use of fertilizers and pesticides. Under these conditions, the main pollutants of groundwater are nitrates, nitrites and ammonium. In the interplastic waters, the medium is strongly reducing, therefore, ammonium and nitrite are predominantly found in them.

As for the second reason for the change in the quality of drinking underground waters of marl and chalk water intakes, the following was noted: the determining factor of water exchange in the basin of the river Siversky Donets is a vertical flow between the aquifers. As a result of long-term coal mining in the study area the processes of vertical overflow between the aquifers intensified even more. Filling in the worked out area of coal mines with deep aquifers has led to deterioration in the quality of MMWG drinking groundwater and overlying aquifers.

Not only the increase in mineralization, but also the appearance of such components as heavy metals and natural radionuclides is recorded in these waters, which is due to their content in coal (Ga, W, Ni, etc.). The transition of these components to groundwater is associated with processes of dissolution, leaching, cation exchange, diffusion, etc.

It should be noted that the above-described pollutant complex, which manifests itself during the first and second pollution processes, does not change in subsequent processes, but has its own characteristic features of distribution. For example, in the analysis of the third pollution process, it has been clarified that the presence of "windows" in the waterproof strata in the study area depends on the geological structure of the terrain and the presence of water-bearing horizons in the roof of the aquifer. There are favorable conditions for penetration of pollutants into the MMWG in parts of the river Siversky Donets' basin where well-filtering varieties (sand, sandy loam, loams) with low sorption properties and a relatively high speed of water flow lie in the roof of the fissured marl-chalk rocks. At the same time, a different picture should be expected in the areas where water-resistant clays lie in the roof of marl-Cretaceous deposits. MMWG is protected from penetration of pollutants in the areas with significant spread of clays with the exception of development areas of "windows", dome structures and open areas of aquifers supply.

The next reason for changing the quality of MMWG waters in the study area is the formation of an extensive depression funnel. In the process of exploitation of the groundwater in this horizon, two depression craters formed in the exploited and overlying alluvial horizon. Decrease in groundwater levels in the center of these funnels is estimated at 120-130 m. Not only did the level fall, but also some reorientation of the direction of the underground stream occured. Thus, in undisturbed conditions, the lines of currents were directed to the channel of rivers feeding them. After the intensification of the water intake, the current lines acquired an orientation toward the center of the depression funnel. At the same time, an extensive depression funnel created additional prerequisites for pulling contaminants to production wells of water intakes.

Numerous water intakes in Kharkiv and Lugansk regions are subjected to the above-described contamination processes. But the most striking example of the complex impact of all of the above pollution processes is the Svetlichansky (1st Donetsk) marly-chalk water intake in Lugansk region. Svetlichansky water intake operates under conditions of infiltration of contaminated sewage from the surface; intensive ascending flow of highly mineralized groundwater carbon; pulling the contaminants to the water intake with a depression funnel. In addition, the situation is aggravated not by the presence of "windows" in the waterproof stratum, but by the absence of this layer. Signs of complex groundwater contamination at this water intake are manifested in a clearly pronounced tendency to increase total mineralization, reduce transparency of water, raising the content of sulfates, chlorides, phenols, some heavy metals and radionuclides.

Thus, the reasons for the deterioration in the quality of drinking groundwater in chalk water intakes, described above, make it possible to systematize the selected complex of actual and potential pollutants in these waters. The selected complex of pollutants includes three blocks of indicators: organic, toxicological and radiation. Further, based on the analysis of the maximum permissible concentrations (MPC) of these pollutants, the groundwater was typified by pollution levels: from non-contaminated to extremely contaminated. Accordingly, groundwater with the content of pollutants within the MPC will have the level of pollution – "within the limits of permissible standards"; relatively polluted – exceeding the norms in 1-2 MPCs, contaminated – 2-3 MPC and exceeding more than 3 MPC – extremely polluted. In this case, groundwater with a level of pollution – "within the limits of permissible standards" and "relatively contaminated", taking into account their quality characteristics and additional post-treatment activities can be used for drinking purposes (table 1).

Table 1

The main pollutants of groundwater

Name of pollutants of groundwater	Level of groundwater pollution			
	Within the limits of permissible standards	Relatively polluted groundwater	Contaminated groundwater	Extremely polluted groundwater
1. Organic, mg/dm³				
Nitrates	≤ 50,0	50,0-100,0	100,0-150,0	≥ 150,0
Nitrites	≤ 0,1	0,1-0,2	0,2-0,3	≥ 0,3
Petroleum products	≤ 0,1	0,1-0,2	0,2-0,3	≥ 0,3
2. Toxicological, mg/dm³				
Be	≤ 0,0002	0,0002-0,0004	0,0004-0,0006	≥ 0,0006
Mo	≤ 0,07	0,07-0,14	0,14-0,21	≥ 0,21
Al	≤ 0,2	0,2-0,4	0,4-0,6	≥ 0,6
Cr	≤ 0,05	0,05-0,1	0,1-0,15	≥ 0,15
Pb	≤ 0,01	0,01-0,02	0,02-0,03	≥ 0,03
Ni	≤ 0,02	0,02-0,04	0,04-0,06	≥ 0,06
Cd	≤ 0,001	0,001-0,002	0,002-0,003	≥ 0,003
As	≤ 0,01	0,01-0,02	0,02-0,03	≥ 0,03
Hg	≤ 0,0005	0,0005-0,001	0,001-0,0015	≥ 0,0015
3. Radiation, Bq/dm³				
Specific activity ^{222}Rn	≤ 100,0	100,0-200,0	200,0-300,0	≥ 300,0
Specific -a, -β – activity	≤ 0,1 ≤ 1,0	0,1-0,2 1,0-2,0	0,2-0,3 2,0-3,0	≥ 0,3 ≥ 3,0
Specific activity ^{137}Cs, ^{90}Sr	≤ 2,0	2,0-4,0	4,0-6,0	≥ 6,0

At the same time in absence of pollution groundwater should differ on qualitative characteristics. In this case, water quality is assessed according to the following indicators: organoleptic, physical-chemical and physiological ones (table 2). The quality of drinking groundwater varies from good to satisfactory. Gradation of water quality is made on the basis of an analysis of relevant standards and already existing classifications. Accordingly, water of good quality will be the water with characteristics that are within the limits of drinking water standards, relatively good – with a slight excess of these norms and waters of satisfactory quality – exceeding the norms by factor of 1.5-2. It should also be noted that exceeding the norms of drinking water quality indicators more than 2 times automatically transfers them to the category of polluted waters (table 1).

Table 2

Main indicators of drinking groundwater quality

Name of drinking water quality indicators, units of measurement	Assessment of water quality at non-contaminated water intakes		
	Good quality	Relatively good quality	Satisfactory quality
1. Organoleptic			
Odor, scores	≤ 2,0	2,0-3,0	3,0-4,0
Aftertaste, scores	≤ 2,0	2,0-3,0	3,0-4,0
Color, degrees	≤ 20,0	20,0-50,0	50,0-80,0
Turbidity, NOC	≤ 1,0	1,0-3,0	3,0-4,0
2. Physical-chemical			
Mineralization, g/dm^3	≤ 1,0	1,0-3,0	3,0-10,0
Total hardness, $mmol/dm^3$	≤ 7,0	7,0-8,0	8,0-12,0
Oxidizing capacity, mg/dm^3	≤ 5,0	5,0-12,0	12,0-20,0
The hydrogen index, Ph	6,5-8,5	8,5-10,0	10,0-14,0
3. Physiological			
I, mcg/dm^3	≤ 50,0	50,0-100,0	100,0-150,0
F, mg/dm^3	≤ 1,5	1,5-3,0	3,0-4,5
Fe (total), mg/dm^3	≤ 0,2	0,2-0,4	0,4-0,6

Conclusions. As a result of the studies, the main sources of groundwater contamination with MMWG have been characterized identifying characteristic pollutant complexes. Taking into account these features, the main criteria for estimating groundwater pollution levels and their qualitative characteristics have been systematized. The systematization was carried out on the basis of the analysis of the standards for MPC and existing classifications. The presented criteria are of a fundamental nature and can be used in studies at various water intakes with similar ecological, geological-hydrogeological and tectonic conditions.

References:

1. *Abramov IB. Assessment of the impact on underground waters of industrial-urban agglomerations and environmental safety: monograph, Kharkiv, 2007; 284.*
2. *State sanitary rules and norms «Hygienic requirements for drinking water intended for human consumption»: SSRN 2.2.4-171-10, Kiev, 2010, № 400; 15.*
3. *Oradovskaya AE. Sanitary protection of groundwater abstraction. Moscow, 1987; 167.*
4. *Udalov IV. Transformation of the geological environment under the influence of technogenic processes in the conditions of the North-Eastern Donbass: monograph. Kharkov, 2016; 176.*
5. *Shestopalov VM. Water exchange in hydrogeological structures of Ukraine: water exchange in disturbed conditions, Institute of Geological Sciences NAS of Ukraine. Kiev, 1991; 528.*