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Ecological Aspects of Arsenic Pollution of the Northern Dagestan Artesian Basin

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Abstract—The problems of arsenic pollution of the North Dagestan basin—the only source of drinking water in northern Dagestan—are considered. The results of monitoring of arsenic in 2002 and 2013 are provided. It is noted that the concentration of arsenic in water is on average 20–30 maximum allowable concentration (MAC). According to preliminary data, its genesis is associated with the migration of arsenic compounds from sand and clay deposits of sedimentary strata of the Pliocene-Pleistocene deposits. Long-term exploitation of the basin with violations of the geotechnical and ecological sanitary standards strengthens the processes of arsenic pollution.

Keywords: artesian basin, arsenic pollution, aquifers

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The North Dagestan artesian basin (NDAB) is the only source of drinking water in northern Dagestan, and therefore its preservation for descendants is an important task. The problem is that the basin waters have been exploited by more than 3000 artesian wells for more than one hundred years at annually increasing rates with violations of exploitation rules and without regard for the recommendations of scientists and specialists. As a result of such unsystematic and uncontrolled exploitation of aquifers and the deterioration of the technical state of wells (more than 60% of wells have passed amortization terms, but their active exploitation continues), the underground waters of overlying and underlying deposits, which contain toxic elements, mix with the fresh underground waters of productive horizons (Kurbanov, 2003). As a result, an increase of mineralization, changes in the chemical composition of water, deterioration of water quality, and, in particular, an increase in arsenic concentrations take place. These signs are one of the elements of ecological stress.

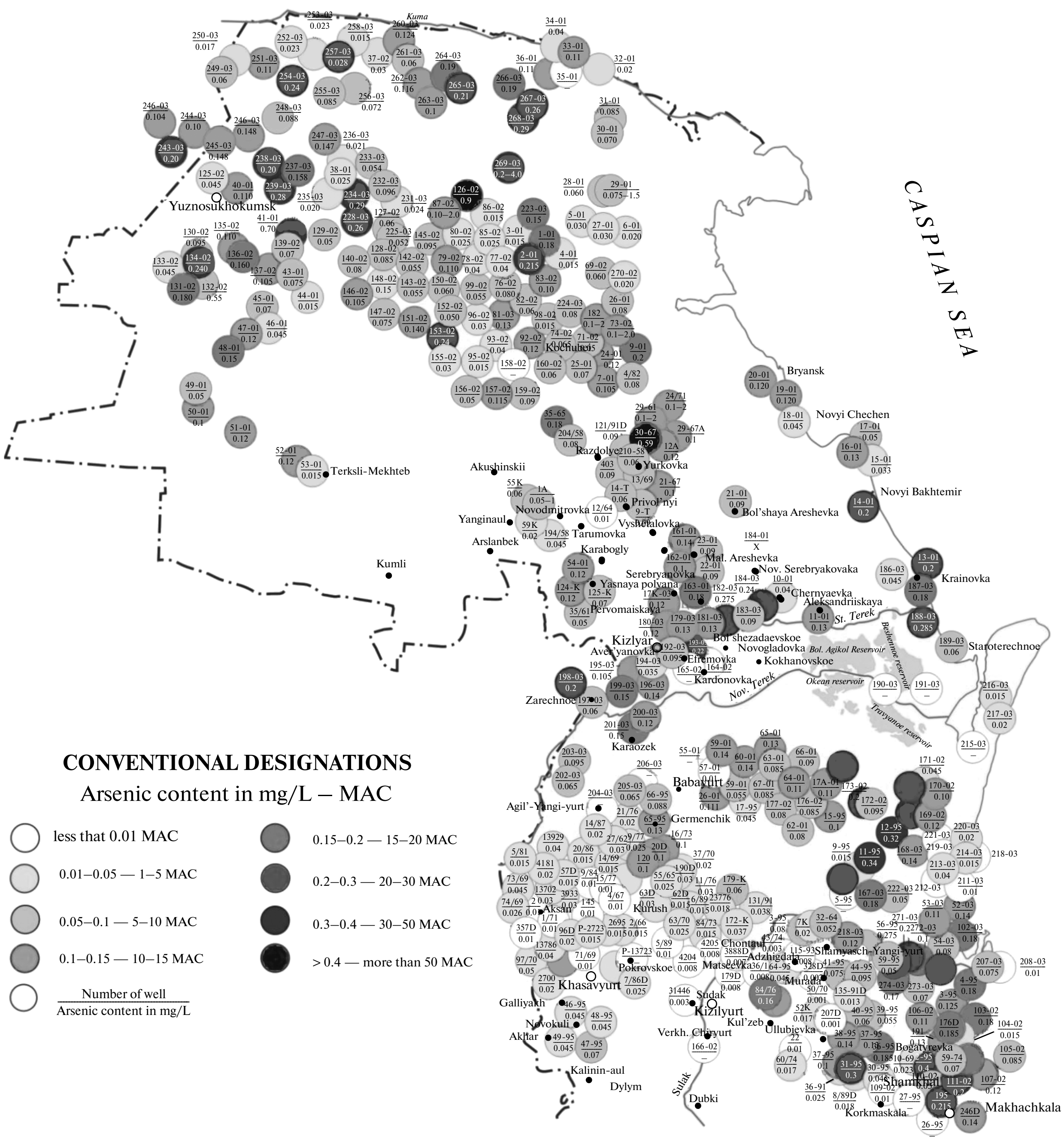
In Dagestan, many organizations (Institute of Geology, Russian Academy of Sciences, Dagestangeomonitoring Research Center, Dagestangeologiya Company) were involved in the study of pollution (including arsenic) of underground waters. However, there is no unambiguous answer to the issue of the causes of arsenic pollution.

Arsenic is among the most dangerous of pollutants, which causes heightened interest in its concentration in drinking waters.

The Laboratory of Hydrogeology and Geoecology of the Institute of Geology of Dagestan Scientific Center, Russian Academy of Sciences, performed studies on arsenic pollution of the Terek-Kuma artesian basin with water sampling for chemical analysis in 2001–2003 (grant no. 01-05-65243 of the Russian Foundation for Basic Research).

As part of the given project, 281 wells on the territory of NDAB were examined. The arsenic content was higher than the norm in 226 (80%) wells, 70% of which contain 4–20 MAC and 15% contain 20–30 MAC of arsenic. The highest indices of arsenic content were recorded in the northeastern part of the basin. The area of arsenic distribution in underground waters is located also in the central part of NDAB–Nogaisk region, which was previously considered favorable: in 78% of the studied wells concentrated between the city of Yuzhnosukhokumsk and Terekli-Mekteb settlement, the arsenic content is 0.06–0.24 mg/L (6.24 MAC). The western part of NDAB–Khasavyurtovskii, Kizilyurtovskii, and Novolakskii regions of the Republic of Dagestan are relatively favorable (*Informatsionnyi byulleten* ..., 2007). The arsenic content in the studied wells of these regions does not exceed 0.04 mg/L, and more than half of the wells do not contain arsenic or contain values within the norm (Kurbanova and Guseinova, 2008; Kurbanova et al., 2013).

According to results of our studies and studies performed by other organizations (Dagestangeologiya Company, Dagestangeomonitoring), the authors compiled a map of arsenic content in underground waters of the North Dagestan artesian basin (figure),



Overview map of arsenic content in the North Dagestan artesian water.

in which the results of chemical analyses of arsenic of about 450 wells are reflected.

To reveal possible changes in the arsenic content over time, a table was compiled on 11 wells for which the arsenic content was determined repeatedly in 2011 and 2013 (table). However, comparative analysis of the obtained results revealed no regularities. This may result from an insufficient amount of data or an insufficient time span of 9–11 years.

According to obtained results of the studies performed, definite conclusions can be derived.

• No regularities in the change in arsenic content in waters in time (8–11 years) were revealed.

• The arsenic content in underground waters increases to the northeast of NDAB, i.e., from feeding regions to areas of transit and the unloading of water-bearing complexes: first in the upper strata of upper-Apsheron and then also in overlying Bakinskii and Khazaro-Khaalynskii water-bearing complexes. This is explained by the fact that overflow from the underlying to the upper water-bearing strata with subsequent evaporation occurs in the expendable part of the

Arsenic content in groundwater

Number in sequence	Sampling site	As content, mg/L		
		2002	2011	2013
1	2	3	4	5
1	Rural district Geolog	0.18	0.19	
2	Kochubei settlement	0.11	0.11	
3	Passing transit 12, Kuma River	0.09	0.18	
4	Yubileinaya square	0.09	0.01	0.02
5	City of Uzhno-Sukhokumsk	0.11	0.16	0.15
6	Dagestan Oil Administration	0.045		0.03
7	Kut. Maiskii	0.16	0.08	
8	Maiskaya square	0.11	0.19	
9	Koktyubei settlement	0.1	0.07	
10	Talovka settlement	0.1	0.06	
11	Polygon Solntse	0.18	0.23	

water balance, which leads to an increase in the total mineralization and arsenic concentrations in the upper aquifer complexes.

• Underground waters with a high arsenic content form in aquifers formed of sandy-clay rocks. These waters mainly have a hydrocarbonate-sodium and chloride-sodium composition. Waters of an intermediate composition—chloride-hydrocarbonate and hydrocarbonate-chloride—also occur. In the cation composition, sodium ions drastically dominate (Ryzhenko et al., 2010).

As for genesis, the causes of increased arsenic content in underground waters are usually proximity to mine operations of tungsten, copper-cobalt, and polymetallic ores. The enrichment industry, pesticide and stain production enterprises, and agriculture are considered the most important arsenic pollutants.

However, there are neither mine operations nor enrichment industry in the considered region. The agriculture mainly involves livestock and is little connected with toxic chemicals. Besides, artesian waters are isolated by weakly penetrable clay layers from the impact of surface pollutants. The arsenic pollution of NDAB is most likely explained by natural causes: arsenic gets into underground waters as a result of geological and biological processes, while the anthropogenic factor has secondary importance.

M.K. Kurbatov advanced a hypothesis that the source of regional arsenic pollution of fresh NDAB underground waters are admixtures of arsenic minerals in some layers of sandy-clay deposits contacting with productive horizons. NDAB may have had a wider distribution in areas of drift, i.e., the northern slopes of the Main Caucasian Ridge, arsenic minerals (realgar AsS, auripigment As_2S_3, auripyrite FeAsS, lellingit $FeAs_2$) in the postakchagyl period of sediment accumulation and formation of Pleistocene strata (*Informatsionnyi byulleten* ..., 2011). Arsenic minerals unevenly distributed in contacting sandy-clay and clay deposits dissolve, are leached, and enter ion-exchange chemical reactions with macrocomponents of underground waters. Under natural conditions, arsenic compounds are apparently adsorbed by clay and sandy-clay particles of aquifers and aquifuges. However, intensification of the heat mass exchange between fluids and mineral particles of rocks occurs under conditions of intense exploitation of artesian wells and the related activation of movement of underground waters (Kurbanova, 2012).

The existing fountain-hydrochemical mode of exploitation at the marginal level, as a result of which water selection by wells increases and decrease in piezometric levels and infiltration from overlying and underlying aquifers of saline waters into productive horizons occurs, also promotes an increase in arsenic concentration. With an increase in the amount of exploitation wells in settlements, the process intensifies and large cones of depression form; they are characterized by maximum arsenic and other forms of pollution (Kondakov et al., 2003; Kurbanov, 1969).

Thus, processes promoting an increase in the arsenic concentration continue, and a single source of fresh underground waters—NDAB—may be subjected to continuous arsenic and other pollution, which can lead to a catastrophe in the water supply to the whole region.

It is necessary to continue the work on revealing the causes of arsenic pollution. It is necessary to identify arsenic admixtures in the whole Pliocene-Pleistocene sediment stratum, the intensity of which varies from 350 to 1000–1200 m.

For this purpose it is necessary to solve the following tasks:

• to determine the quantitative concentration of arsenic minerals in sedimentary strata of the artesian basin;

• to determine the forms of occurrence and the regularities of their distribution with depth;

• to determine the physicochemical and water-physical properties of arsenic minerals and mineral associations confined to the productive stratum of the fresh underground waters of NDAB;

• to reveal the degree of arsenic pollution of the Terek-Kuma artesian basin, of which NDAB is a component.

Isotopic methods, which are more rapid and inexpensive than nonisotropic methods, are used in some countries to obtain precise information on arsenic pollution. The data obtained by the given method also make it possible to perform an exact evaluation of the dynamics of aquifer and underground waters. Thus, they help to establish whether deep aquifers will remain without arsenic admixtures for a prolonged time, whether they can be used as alternative sources of fresh water, and whether they can be as polluted as other deep aquifers because of the mixing of deep and nondeep strata (Kurbanova, 2012).

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