International Journal of GEOMATE, Nov., 2018 Vol.15, Issue 51, pp.22-30
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.51.09290
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

CHANGES IN THE QUALITATIVE CHARACTERISTICS OF GROUNDWATER OF THE OSSETIAN ARTESIAN AQUIFER

*Vladislav Zaalishvili[1], Avtandil Dzhgamadze[1], Rudik Gogichev[1], Boris Dzeranov[1], Olga Burdzieva[1]

[1] Geophysical Institute VSC RAS, Russia

*Corresponding Author, Received: 25 March 2018, Revised: 24 May 2018, Accepted: 8 June 2018

ABSTRACT: The basis for the research was the GIS project, which includes groundwater monitoring data on the territory of the Republic of North Ossetia-Alania. The paper presents generalized materials on fresh groundwater and comparative analysis of their quality change during water intake exploitation on the territory of the Republic of North Ossetia-Alania. Special geoinformation system (GIS) including groundwater parameters data for about 20 years of monitoring was developed. The results of chemical analyzes of groundwater for different years are systematized. The characteristics of deformation changes in aquifers and their relationship to surface waters are given. The evaluation of the groundwater protection against natural and anthropogenic pollution is given. The methodology for calculating of protective sanitary zones for water intakes with various hydrogeological conditions is developed, and measures for sanitary protection and revealing of pollution sources are offered (reasons for increasing hardness and mineralization of fresh groundwater in the industrial zone of Vladikavkaz city). Based on the investigation results, the conclusions on possible sources of hardness increase and deterioration of groundwater quality in the Ossetian artesian aquifer were drawn.

Keywords: Well, Water intake, Aquifer, Water hardness, Mineralization.

1. INTRODUCTION

For the last 20 years in the operational aquifer, in the southern part of the Ossetian artesian aquifer, and specifically in the industrial zone of Vladikavkaz, the quality of groundwater has deteriorated. There is a steady tendency to increase of water hardness and a corresponding mineralization [1]. Mineralization in the water intake well can increase due to the suction of mineralized waters from other aquifers or the entry of surface contaminants into the aquifer. The increase of groundwater hardness is observed in the northern (industrial) part of the city. According to preliminary data, it was caused by the anthropogenic impact on the geological environment [2]–[3] in the conditions of high exogenous [4] and endogenous hazards [5]–[7].

2. STUDY OF GROUNDWATER

Water hardness is a certain property of water, which is associated with dissolved magnesium and calcium compounds, in other words, the presence of cations of these elements in water. Water hardness in many respects determines its suitability for use both for industrial and domestic purposes. Water hardness is usually calculated as the sum of millimoles of calcium and magnesium ions per 1 liter of water (mmol/L).

The total hardness (Ht) is the total concentration of Ca^{2+} and Mg^{2+} ions in water, expressed in mol/m^3 or $mmol/dm^3$. The total hardness of water (Ht) is equal to the sum of carbonate and non-carbonate hardness.

$$H_t = [Ca^{2+}] + [Mg^{2+}] = H_c + H_{nc}; \ (\text{mmol/dm}^3) \quad (1)$$

Quantitatively, the water hardness is determined by the sum of the molar concentrations of the equivalents of calcium and magnesium ions contained in 1 dm^3 of water ($mmol/dm^3$, mg-equ/dm^3).

Carbonate (temporary) hardness (H_c) is caused mainly by a concentration of hydrocarbonates (and carbonates at pH > 8.3) calcium and magnesium salts in the water: $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, ($MgCO_3$).

Non-carbonate hardness (H_{nc}) is caused by the presence of sulfates and chlorides of calcium and magnesium salts in the water: $CaSO_4$, $MgSO_4$, $CaCl_2$, $MgCl_2$. Non-carbonate hardness is a part of the total hardness equal to the difference between the total and carbonate hardness:

$$H_{nc}=H_t-H_c \quad (2)$$

According to the hardness value, natural water is divided into very soft - up to 1.5 $mmol/dm^3$; soft – from 1.5 to 4 $mmol/dm^3$; medium hardness – from 4 to 8 $mmol/dm^3$; hard – from 8 to 12 $mmol/dm^3$ and very hard – over 12 $mmol/dm^3$.

Depending on the specific production requirements, the permissible water hardness can be different. The water hardness in utility and drinking water pipelines should not exceed 7 mmol/dm^3 (mg-equ/dm^3).

The cause of water hardness is underground deposits of limestone, gypsum and dolomite, which are dissolved in groundwater and also due to the other processes of dissolution and weathering of rocks. Usually, the water hardness caused by calcium ions (up to 70-80%), predominates in low-mineralized waters (although, in some rare cases, magnesium hardness can reach 50–60%). With an increase in the degree of water mineralization, the content of calcium ions (Ca^{2+}) decreases rapidly and rarely exceeds 1 g/L.

Permissible water hardness for drinking needs depends on specific hydrogeological conditions.

Hard water has a bitter taste and negatively affects the digestive organs; its organoleptic properties correspond to a low level. If in the case of prolonged use, without appropriate preventive measures, water with a high content of calcium salts is capable of destroying even the most wear-resistant metal, then how harmful can be the effect of hard water on the human body?

The largest hydrogeological structure on the territory of North Ossetia-Alania is the Ossetian artesian aquifer. Hydrogeological conditions of the Ossetian artesian aquifer (the Ossetian sloping plain) are conditioned by its location in the junction zone of the Greater Caucasus structures and the Tersk-Caspian foretrough. [8]–[11].

Geological and hydrogeological characteristics of the Ossetian artesian aquifer (OAA) are based on the groundwater monitoring data carried out by the JSC “Sevosetingeoekomonitoring” and the results of the previous hydrogeological investigations.

The northern boundary of the aquifer passes along the watershed line of the Sunzhensk (Malo-Kabarda) Range, the southern one passes at the foot of the Lesistyi Ridge. In the east, the North Ossetian artesian aquifer is separated from the Sunzhensk by Nazran-Yandir and Datykh Uplands. In the west, the basin delineates the Zmeisk Uplift (Zmeisk Ridge).

Absolute marks on the surface of the OAA vary from 800 to 320 m, with a general slope to the north-west to the “Elkhotovo Gate”, the discharge zone.

OAA is composed of a thick stratum of Holocene-Pleistocene boulder-pebble deposits with rare interlayers and lenses of sand, sandy loam, loam, and clay.

Within the Ossetian artesian aquifer, the first water-bearing alluvial-fluvioglacial Quaternary complex (afQ_{I-III}) is the main source of utility and drinking water supply, on the basis of which the main water supply of North Ossetia-Alania is carried out (Fig. 2).

The aquifer has almost ubiquitous development in the flat part of the plain. The thick stratum of pebbles, boulder-pebble with sandy and sandy-clay aggregate is water-bearing. The thickness of the water-bearing materials along the periphery of the plain varies 10–20 m in the central (axial) 150–300 m [12]–[13]. The absence of aged water-resistant clay interlayers in the section determines the pressureless filtration mode [14].

The groundwater depth in the southern, eastern and western periphery of the aquifer is 150–50 m, in the central part 50–15 m and in the northwestern part, characterized by the presence of numerous outcrops of groundwater in natural depressions of the relief, varies from 15–10 to 0.1 m.

The rates of concentrated descending springs covering a considerable area (about 85 km^2) vary from 15–30 to 350–700 dm^3/s, and the total discharge of the discharge zone (springs and discharge into river beds), according to the latest estimates of regional works, amounts 13.9 m^3/s and indicate the considerable water abundance of Quaternary sediments and sufficiently high filtration properties of the water-bearing rocks in this area.

The direction of groundwater movement in the OAA coincides with the flow of the rivers, and the slope of the ground flow varies from 0.003 to 0.0068, with large values in the northwestern part of the aquifer, which is the zone of natural groundwater discharge.

The highest water abundance level of the Quaternary aquiferous complex of OAA is noted in the northern part, where the calculated conductivity is 7500 m^2/day [15]–[16].

In the central, the most over-deepened part of the aquifer, the water conductivity of the aquiferous rocks varies from 1568 to 4685 m^2/day with an average calculated value (Beslan Groundwater Deposit) – 3145 m^2/day, the production well rates are 17–45 dm^3/s, and the specific rates vary from 14.6 to 29.4 dm^3/s. In the southern part (the northern suburbs of Vladikavkaz), in the eastern and western parts of the OAA, the water conductivity decreases to 1500-900 m^2/day and the specific rates of the wells at the periphery of the aquifer is lower (0.3–3.5 dm^3/s).

The nourishment zone of the aquiferous alluvial-fluvioglacial Lower-Upper Pleistocene complex coincides with the area of its distribution. The nourishment is provided by the infiltration of atmospheric precipitation, the absorption of rivers surface runoff, which determines the groundwater level regime, which is closely related to climatic and hydrological factors.

The greatest amplitude of seasonal fluctuations in the level of groundwater (6–7 m) is observed in the southern part of the OAA.

The amplitude of fluctuations in the

groundwater level of the OAA, below the contour of the zone of regional natural discharge, in the northern part of the aquifer, does not exceed 0.2–0.3 m.

The natural discharge of the occurs into the river net and in the form of springs, evaporation from the free surface in shallow-lying areas of the level, and also through the underground flow through the “Elkhotovo Gate”.

According to the chemical composition, the water is mainly bicarbonate calcium, sulfate-hydro carbonate magnesium-calcium, with a mineralization of 0.3–0.7 g/dm^3 and is safe in a sanitary-bacteriological respect.

According to hydrochemical testing of the water-bearing complex in hydrogeological wells till the mid-1980s in the north-eastern right-bank part of Vladikavkaz, the quality of groundwater was in accordance with the requirements for drinking water. The water hardness was 4-6 mg-equ/dm^3 (the norm is 7.0), and the mineralization did not exceed 0.5 g/dm^3 (the norm is up to 1 g/dm^3) (Fig. 1).

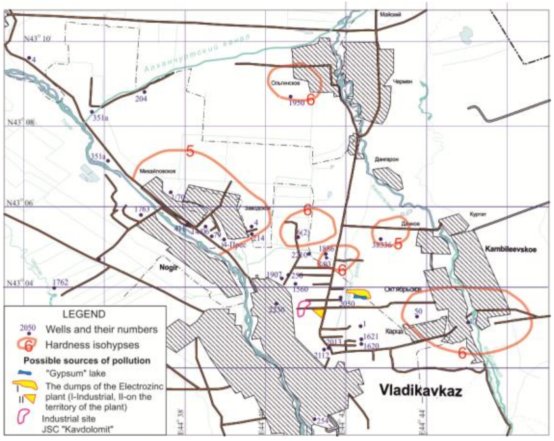

Fig. 1. The map of the groundwater hardness in the north-eastern part of Vladikavkaz until 1985.

For the first time, increased water hardness, which amounted to 12.5 mg-equ, was detected in the northern suburbs of Vladikavkaz when drilling the well No. 79 - LLC “Forward-S” in 2000.

As a result of conducted hydrogeological research for 2005-2008, the reserves of fresh groundwater of the “Severny” area were studied and counted. The area includes water intakes: CJSC “Ariana”, LLC “Forward-S”, LLC “Lux”, OJSC “Daryal” and “Sevospotrebsoyuz, Vladikavkaz Food Production Factory”.

According to physicochemical investigations, the groundwater in the wells of the water intake sites is cold (temperature 9–12º), the level of total mineralization (0.5–0.9 g/dm^3) of the water is slightly mineralized, fresh (dry residue 0.41-0.68 g/dm^3) of hydrocarbon, sulphate-hydro carbonate calcium, magnesium-calcium composition: HCO3 43–70, SO_4 10–30, Ca 55–86, Mg 8–25, Na+K 3.3–19.8 equ. % with the reaction of the medium from weakly acidic to slightly alkaline (pH 6.9-7.85). The total hardness of water is 6.9–11.0 mg-equ/dm^3 [17].

The chemical composition of the water, taken from the wells, can be represented as follows:

No. 79 (LLC “Forward-S”)

$$M\,0.8\text{-}0.9\,\frac{HCO_3 63-66\,SO_4 21}{Ca 69-73\,Mg 20\text{-}24}\,pH\,7.8\text{-}7.9 \qquad (3)$$

No. 6 (2) (LLC “Lux”)

$$M\,0.5\text{-}0.8\,\frac{HCO_3 58-65\,SO_4 24-30}{Ca 70-86\,Mg 8\text{-}25}\,\text{pH}7.2\text{-}7.4 \qquad (4)$$

No. 1-96 (CJSC “Ariana”)

$$M\,0.6\text{-}0.8\,\frac{HCO_3 43-73\,(SO_4 10-14)}{Ca 73-79\,Mg 18\text{-}20}\,pH\,7.0\text{-}7.2 \qquad (5)$$

No. 2210 (OJSC “Daryal”)

$$M\,0.7\text{-}0.8\,\frac{HCO_3 43-47\,SO_4 41-44}{Ca 74-79\,Mg 12\text{-}15}\,pH\,6.9\text{-}7.0 \qquad (6)$$

In the water of all wells, toxic and normalized trace elements, including heavy metals (lead, cadmium, chromium, arsenic, etc.), nitrogen compounds (nitrites, nitrates, ammonium), and strontium (natural and anthropogenic) are not found, or their concentrations are below the maximum permissible level for fresh groundwater (SanPiN 2.1.4.1074-01).

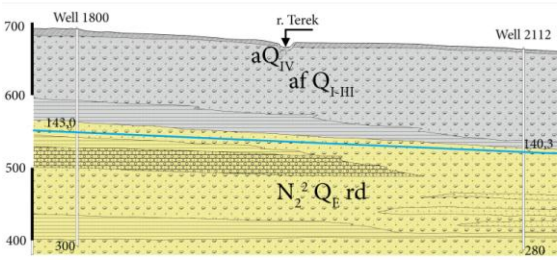

Fig. 2. The geological and hydrogeological section of the investigated area (aQ_{IV}- alluvial sediments of modern origin; $afQ_{I\text{-}III}$ - alluvial-fluvioglacial alluvial fluvioglacial sediments of lower-upper-Quaternary age; $N_2^2Q_E$rd - sediments of the Rukhs Dzuar suite)

Thus, the quality of groundwater obtained from the wells of the water intake areas of LLC “Forward-S”, LLC “Lux”, CJSC “Ariana”, OJSC “Daryal”, is good in all respects and meets the requirements for water quality of centralized drinking water supply system of SanPiN 2.1.4.1074-01 “Drinking water”, with the exception of hardness.

A similar situation is also observed at the Zavodskoy well water intake, from which the drinking water supply of the village Zavodskoy of Industrial District of Vladikavkaz is performed, (about 40 thousand people).

Based on the results of exploration work at the Zavodskoy site of groundwater from 2009 till 2013 (LLC "Gidro plus" Dzhgamadze A.K., Pashchenko A.A.) there was an increase of the groundwater hardness [2].

In the Zavodskoy site of groundwater, water intake wells are capping the upper part of the Akchagyl-Apsheron aquifer complex. Water-bearing rocks are represented by gravel-pebble sediments and conglomerates and contain cold (10-12 °C) confined groundwater, which is related to fresh waters (0.5-0.8 g/dm^3) according to the level of total mineralization [18].

According to the research conducted during the drilling of wells in 1975–1976, it was found that the composition of groundwater is hydro carbonate calcium, magnesium-calcium. The water is odorless, the transparency is less than 30 cm, there is no turbidity, the total water hardness does not exceed 5.2 mg-equ/dm^3, the dry residue is 0.2–0.3 g/dm^3, the calcium content in water is 50 mg/L, sulfates - 10–40 mg/L, chlorine - 7.0–10.0 mg/L.

Based on the results of hydrochemical testing by a subsoil user, since 1991, the water hardness has increased. The dynamics of hardness change on the site is the following: 1975–1990 - 3–5 mg-equ/dm^3; 1991–1998 – 5–7 mg-equ/dm^3; 1999–2000 - 8–9 mg-equ/dm^3; 2001 - 9–11 mg-equ/dm^3; 2002–2005 – 7–8 mg-equ/dm^3; 2008 - 9-14 mg-equ/dm^3; 2009 – 8–14 mg-equ/dm^3; 2010 – 8–15 mg-equ/dm^3; 2012 – 12–15 mg-equ/dm^3; 2013–2017 – 9.8–11.2 mg-equ/dm^3.

The dry residue for the indicated period has changed from 0.3–0.4 g/dm^3 to 0.7 g/dm^3 in 2007. The chlorine content changed from 20 to 60 mg/dm^3.

The general chemical composition of groundwater in an operational aquifer is expressed by the following formula:

$$M0.5-1.0\frac{HCO_3 50-63SO_4 20-37(Cl9-18)}{Ca72-79Mg17-25} \quad (7)$$

The water hardness varied within the range of 6.9–13.5 mg-equ/dm^3, and the mineralization 0.5–1.0 g/dm^3. The calcium content is 99–200 mg/dm^3, the hydrocarbon is 262–427 mg/dm^3, the chlorine is 28.4-64.5 mg/dm3, the sulfates are 80.7–235.4 mg/dm^3. It should be noted that the mineralization of water increased in the well No.2 in the water sample taken in January 2013, where it was 1.0 g/dm3 with a hardness of 11.6 mg-equ/dm^3. The sulfate content in the sample was 235 mg/dm^3.

Within the halo of increased groundwater hardness starting from 2008, 12 main water intakes are monitored. All water intakes are located in the right-bank part of Vladikavkaz.

As a result of monitoring observations (annual sampling of water wells of various enterprises in Vladikavkaz - JSC “Sevosetingeoecomonitoring”), the following data were obtained for the hardness indicators of groundwater:

The source of increased hardness of groundwater based on the results of 30 analyzes performed as a result of testing water intake wells retains its spatial and quantitative parameters (Table 1).

In 12% of the tested wells (within the area of increased hardness), the hardness indices remain at the level of 2014. In 25% of the tested wells, the hardness indices are slightly lower than in 2014. In 62% of the tested wells, the hardness indices are higher than those of 2014.

Besides the north-eastern industrial zone, the testing results of several water intakes in the western left-bank part of the city were analyzed in order to determine the trend of the previously established background values of hardness and mineralization.

Table 1 Characteristics of hardness and mineralization indicators

No.	Well number, aquifer	Hardness, mg-equ/L	Date of water sampling
1	3	4	6
Industrial zone of Vladikavkaz city, the right bank of the river Terek			
1	1907	6.6	31.07.89
	afQ	18.2	16.08.08
		16.3	14.05.09
		14.8	20.06.10
		15.0	19.09.11
		8.1	1.10.12
		14.6	12.08.2013
		7.4	1.08 2014
		10.2	19.11.2015.
		13.7	12.10.17
2	1620	5.4	10.10.82
	1621	5.4	31.12.82
	afQ	5.1	12.08.2013
3	1884	3.4	30.03.89
	afQ	6.9	5.05.06
		9.73	19.08.06
4	1886	7.6	9.03.89
	afQ		
5	1-96	8.6	9.07.08
	afQ	8.6	16.08.08
		8.0	20.06.10
		8.4	19.09.11
		3.4	23.10.17

No.	Well number, aquifer	Hardness, mg-equ/L	Date of water sampling
1	3	4	6
6	2112	7.0	22.08.05
	afQ	8.0	18.12.07
		8.0	18.03.08
		5.5	25.06.08
		9.0	16.08.08
		6.5	14.05.09
		11.2	14.04.09
		6.3	20.06.10
		6.4	19.09.11
		6.0	1.10.12
		5.7	12.08.2013.
		4.7	01.08.2014.
		7.9	19.11.2015.
		5.8	12.10.17
	2113	7.2	18.12.07
	afQ	6.0	18.03.08
		6.6	25.06.08
		8.1	12.08.2013
		8.2	2.10.2014
		5.4	19.11.2015.
		8.0	12.10.17
7	2050	5.5	2000
	afQ	6.8	20.06.10
		6.3	1.10.12
8	6(1)	6.63	19.07.01
	afQ	7.8	20.06.10
		10.0	19.09.11
		6.7	01.08.2014
		6.9	19.11.2015
		12.4	12.10.17
	6(2)	7.0	2001
	afQ	7.0	10.10.02
		7.9	12.06.05
		6.9	16.08.08
		7.6	14.05.09
		6.8	12.08.2013
		8.0	04.09.2013
	6(4),afQ	7.5	1.10.12
9	8/03	7.0	2004
	afQ	7.7	08.03.05
		8.7	20.06.10
		9.1	19.09.11
		6.8	1.10.12
		8.8	12.08.2013
		8.8	01.08.2014
10	4	4.05	21.05.76
	afQ	8.0	22.08.05
		13.5	16.08.08
		13.1	14.05.09
		12.5	20.06.10
		13.0	19.09.11
		12.6	1.10.12
		12.2	12.08.2013
		9.8	01.08.2014
		8.9	2.10.2014

No.	Well number, aquifer	Hardness, mg-equ/L	Date of water sampling
1	3	4	6
		9.2	19.11.2015
		11.2	12.10.17
11	2210	9.9	2001
	afQ	9.9	08.03.05
		9.3	16.08.08
		8.7	14.05.09
		8.2	20.06.10
		8.5	19.09.11
		8.6	12.08.2013
		8.2	01.08.2014
		8.1	19.11.2015
		7.7	12.10.17
12	1560	9.0	12.10.17
13	250	5.3	1973
	afQ	15.3	10.11.08
		15.5	1.10.12
		15.7	22.04.13
		16.0	12.08.2013
		14.4	01.08.2014
		9.4	19.11.2015
		9.6	12.10.17
14	2230	8.5	19.06.06
	afQ	9.0	07.07.06
		9.5	16.08.08
		9.3	14.05.09
		8.9	20.06.10
		9.1	19.09.11
		8.4	1.10.12
		8.1	12.08.2013
		7.9	19.11.2015
15	79	12.5	5.10.00
	afQ	12.1	16.10.00
		11.0	11.02.08
		9.5	19.09.11
		8.6	1.10.12
		9.5	12.08.2013
		10.0	01.08.2014
		7.9	19.11.2015
			12.10.17
16	411	3.4	04.04.90
	afQ	4.4	28.09.05
		4.9	14.05.09
		4.1	1.10.12
		4.6	12.08.2013
		4.6	01.08.2014
		5.3	2.10.2014
		5.8	19.11.2015
		4.5	12.10.17
17	14/06	-	10.04.74
	afQ	4.6	16.09.08
		3.5	12.08.2013
		7.3	19.11.2015
		7.3	12.10.17
18	1/70	5.3	1.10.12
	afQ	5.1	12.08.2013

No.	Well number, aquifer	Hardness, mg-equ/L	Date of water sampling
1	3	4	6
		5.8	01.08.2014
		6.3	2.10.2014
		5.5	19.11.2015
		6.2	12.10.17
19	214	8.5	19.11.2015
	afQ	9.3	12.10.17
20	4	11.7	1.10.12
	afQ	12.1	12.08.2013
		12.8	01.08.2014
21	334	5.2	12.08.2013
	afQ	5.4	01.08.2014
		5.5	19.11.2015
		6.2	12.10.17
22	38336	6.2	1.10.12
	afQ	6.2	12.08.2013
		6.1	2.10.2014
		5.9	19.11.2015
		5.8	12.10.17
23	no numb.	6.1	2.10.2014
	afQ	6.2	19.11.2015
		6.3	12.10.17
	no numb. 2	5.8	23.10.17
	The left bank of the river Terek		
24	1763	5.5	12.09.86
	afQ	4.7	16.08.08
		4.4	1.10.12
		4.6	12.08.2013
		4.8	01.08.2014
		5.	2.10.2014
		5.2	19.11.2015
		5.5	12.10.17
25	1762	5.2	0,415.86
	afQ	4.0	27.07.05
		4.7	16.08.08
		4.8	12.08.2013
		5.1	01.08.2014
		3.5	12.10.17
26	no numb.	5.9	20.06.10
	afQ	5.5	19.09.11
		5.4	1.10.12
		5.0	12.08.2013
		5.3	01.08.2014
		5.5	2.10.2014
		5.0	19.11.2015
		5.9	12.10.17
27	254	4.9	1.10.12
	1588	4.6	12.08.2013
	Q_E	4.7	01.08.2014
		5.0	2.10.2014
		6.0	19.11.2015
		6.0	12.10.17
28	no numb. Q_{III-IV}	3.6	2.10.2014
29	9 (1629)	5.1	2.10.2014
	Q_{III-IV}	5.0	19.11.2015

No.	Well number, aquifer	Hardness, mg-equ/L	Date of water sampling
1	3	4	6
30	275 afQ	4.9	2.10.2014
31	17	6.5	2.10.2014
	afQ	6.2	19.11.2015
		5.4	12.10.17
32	50	6.5	19.11.2015
	afQ	6.9	12.10.17
33	552	4.3	2.10.2014
	afQ	4.0	19.11.2015
34	132	5.5	2.10.2014
	afQ	5.4	19.11.2015
		5.3	12.10.17
	129 (3)	6.8	16.09.2014
35	afQ	6.1	19.11.2015
		6.0	12.10.17
	4	6.4	12.10.17
36	no numb.		16.09.2014
	afQ		19.11.2015
	204	6.9	12.10.17
37	162	6.4	12.10.17 .
38	28 (2n)		31.03.2014
	afQ	3.8	12.10.17
39	374a	6.0	24.10.2013
40	112	6.2	2.10.2014
	afQ	5.8	19.11.2015
41	1802	6.3	2.10.2014
	afQ	4.0	19.11.2015
		5.0	12.10.17
42	1 afQ	4.0	2.10.2014
43	38234 afQ	5.1	2.10.2014
44	1 afQ	6.5	2.10.2014
45	1663 afQ	5.1	2.10.2014
46	no numb. afQ	4.3	2.10.2014
47	no numb. afQ	4.8	2.10.2014
48	68	5.1	24.10.2013
49	2090	3.7	19.11.2015
	afQ	3.9	12.10.17
50	2/89	7.5	24.10.2013
		6.3	2.10.2014
		5.5	19.11.2015
51	14	3.2	24.10.2013
52	1950	6.2	12.10.17
53	4	6.4	12.10.17
54	4–16	4.6	12.10.17

In order to determine the borders of contamination halo distribution in the direction of groundwater flow, as in 2014 and in 2015, the sampling area was significantly expanded: water intakes were sampled on the southern outskirts of the village. Mikhailovskoe, Beslan, Prigorodny district (Sunzha village, Oktyabrskoye village), Ardon town, villages Mostizdakh, Kadgaron, and Krasnogor. The hardness indicators here varied from 3.5 to 6.8 mg-equ.

Thus, the halo of increased hardness of groundwater (more than 7 mg-equ) is limited to the right-bank part of Vladikavkaz within the industrial zone of the city, where the excess of the norm ranges from 1.1 to 1.5 units of the maximum permissible level.

An insufficient information volume does not allow determining unambiguously the reasons for the hydrogeochemical processes occurring in groundwater and, in general, in the geological environment in this area.

In order to find out the true causes of the occurred processes, it is necessary to set up a special thematic work that provides a comprehensive approach to the study of the problem, the data processing of which will allow us determining the sources of groundwater pollution and trace the dynamics of groundwater conditions.

The main reason for the lack of information is the lack of object monitoring data, which must be carried out by the enterprises that have a license for the right to use groundwater.

The distribution halo borders of the increased hardness, according to the results of testing in dynamics for the period 2008–2017 are presented in Figures 3–6.

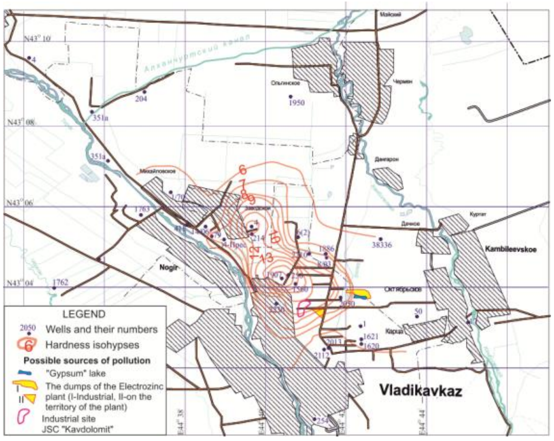

Fig. 3. The map of the groundwater hardness in the north-eastern part of Vladikavkaz for 2008.

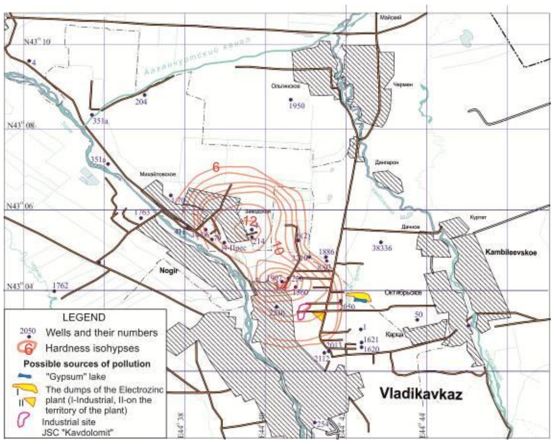

Fig. 4. The map of the groundwater hardness in the north-eastern part of Vladikavkaz for 2010.

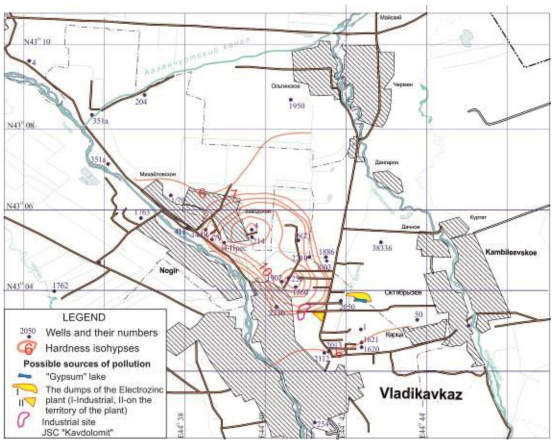

Fig. 5. The map of the groundwater hardness in the north-eastern part of Vladikavkaz for 2012.

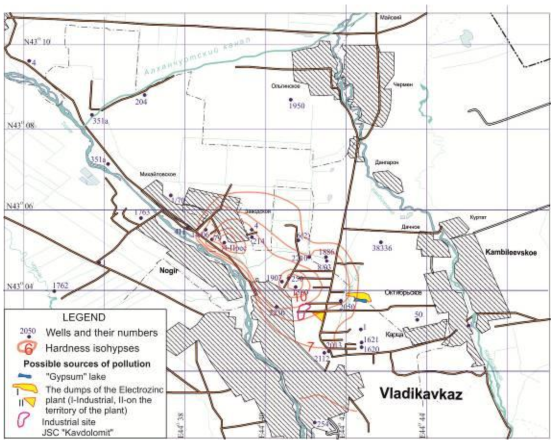

Fig. 6. The map of the groundwater hardness in the north-eastern part of Vladikavkaz for 2014.

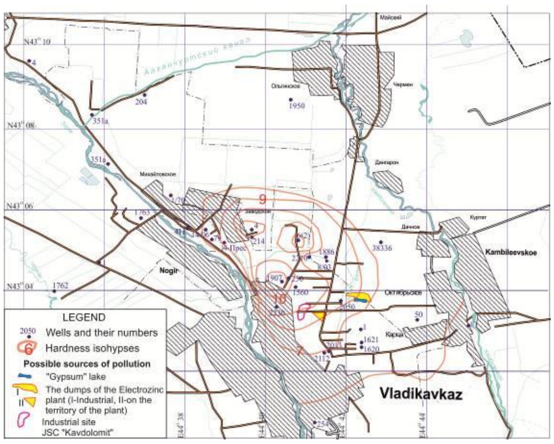

Fig. 7. The map of the groundwater hardness in the north-eastern part of Vladikavkaz for 2017.

3. CONCLUSIONS

Presumably, one of the reasons of the change for the worse in the quality of groundwater in the aquifers of the Quaternary sediments and the deposits of the Rukhs-Dzuar suite may be the anthropogenic deposits of the Electrozinc plant, including the so-called “Gypsum lake” and industrial site of JSC “Kavdolomit”. Pollution is caused by the spraying of dolomite flour, followed by its dissolution and filtration into the aquifer of Quaternary sediments and sediments of the Rukhs-Dzuar suite.

An adverse impact on groundwater quality and water quality deterioration, undoubtedly, can be caused by the decomposing polygons of slagheap of industrial metallurgical enterprises OJSC “Electrozinc” and OJSC “Pobedit”. This threatens the future use of the fresh groundwater in the huge reservoir of the North Ossetian artesian aquifer.

Such sudden changes in the quality of groundwater were not observed in other parts of the Vladikavkaz.

It is necessary to note the unexplored problem of increasing hardness (mineralization), as well as the content of organic pollutants in a significant right bank area of Vladikavkaz, and the area of Beslan Groundwater deposit. Since 2007, the observations are underway for the dynamics of a hardness halo development and nitrogen-containing compounds.

In order to establish the boundaries of the groundwater pollution source and to adopt recommendations for its prevention, special hydrogeological and ecological studies should be carried out, including groundwater monitoring.

The issues covered in the present article are vital for many other urbanized territories and results obtained in these investigations can be applied in other water supply planning of different cities all over the world.

4. REFERENCES

[1] Dzeranov B.V., Gogichev R.R., Dzhusoeva N.G. GIS-technologies use in the groundwater quality assessment of the Republic of North Ossetia-Alania // Geology and Geophysics of the South of Russia. - 2017. - № 3. - P. 40-56.

[2] Dzhgamadze A.K., Kolesnikova A.M., Oganesyan S.M. Engineering and geological conditions of the southern, resort part of the administrative district of Vladikavkaz and the state of the life support system (water supply) of the population // Sustainable development of mountain areas. - 2016. - Vol. 8. № 1. - P. 33-45.

[3] Burdzieva, O.G., Zaalishvili, V.B., Beriev, O.G., Kanukov, A.S., Maysuradze, M.V. Mining impact on the environment on the North Ossetian territory // International Journal of Geomate, 2016. T. 10. No 1. – P. 1693-1697

[4] Zaalishvili, V.B., Mel’kov, D.A. Reconstructing the Kolka surge on September 20, 2002 from the instrumental seismic data // Izvestiya, Physics of the Solid Earth, 2014.- Vol. 50, Issue 5, - P. 707-718

[5] Zaalishvili, V.B., Rogozhin, E.A. Assessment of seismic hazard of territory on basis of modern methods of detailed zoning and seismic microzonation // Open Construction and Building Technology Journal, 2011, Vol.: 5, - P. 30-40

[6] Zaalishvili, V.B. Measurement and recording equipment for seismic microzonation // Measurement techniques, 2016, T.: 58, Vol.: 12, - P. 1297-1303

[7] Zaalishvili, Vladislav; Melkov, Dmitry; Kanukov, Alexandr; Dzeranov Boris. Spectral-temporal features of seismic loadings on the basis of strong motion wavelet database // International journal of Geomate, 2016, T,: 10, Vol.: 19, P. 1656-1661

[8] Muzaev I.D., Kharebov K.S., Muzaev N.I. The mathematical model, algorithm and the program for the design of selective water intake systems. // Izvestiya Vysshikh Uchebnykh Zavedenii. North-Caucasian region. Series: Engineering sciences. - 2016. - No. 1 (186). - P. 84-90.

[9] Zaalishvili V.B., Kolesnikova A.M., Dzhgamadze A.K. Geological and tectonic features of the Mozdok depression of the Tersko-Kumskiy downfold and the territory of the town Mozdok. // In the collection: Seismic hazard and seismic risk management in the Caucasus. Proceedings of the V Caucasian International School-Seminar of Young Scientists / Editor: V.B. Zaalishvili. - 2013. - P. 133-139.

[10] Zaalishvili, V.B., Burdzieva, O.G., Dzhgamadze, A.K. Geothermal waters of North Ossetia // Ecology, Environment and Conservation, 2015 – T. 21. No 5- P. 151-155
[11] Zaalishvili V.B, Chotchaev Kh.O., Burdzieva O.G., Gogichev R.R. Prospects for the development and the use of deep hydrothermal and petrothermal foci in the mountainous area of North Ossetia // Geoenergy. Materials of the II International Scientific and Practical Conference. - 2016. - P. 116-130.
[12] Zaalishvili, V.B.; Nevskaya, N.I.; Nevskii, L.N., Shempelev A.G. Geophysical fields above volcanic edifices in the North Caucasus // Journal of Volcanology and Seismology, 2015, T: 9, No 5. - P. 333-338
[13] Shempelev, A.G.; Zaalishvili, V.B.; Kukhmazov, S.U. Deep structure of the western part of the Central Caucasus from geophysical data // Geotectonics, 2017, T.: 51, Vol.: 5, P. 479-488
[14] Dzeranov B.V., Dzhgamadze A.K., Zaalishvili V.B. The features of hydrogeological conditions of the location of Vladikavkaz, affecting the seismicity of the territory // Proceedings of young scientists of the Vladikavkaz Scientific Center of the Russian Academy of Sciences. - 2010. – No 3. - P. 145-150.
[15] Popov V.Z. Report on the theme: "Engineering and geological supplementary exploration of the Dallagkau landslide" // LLC "Center of Geodynamic Research". - M. - 2007. 203p.
[16] Zharenov A.P. Report on the theme: "Complex analysis of the results of the Dallagkau landslide" / JSC "Institute Hydroproject", the branch of the Center for Geodynamic Observations in the Electricity Industry - M. - 2003. 130 p.
[17] Zaalishvili V.B., Dzhgamadze A.K. The features of fresh groundwater resources estimation under the conditions of exploitation of interdependent water intakes by taking seismic hazard of the territory into account // Seismic construction. Safety of buildings. - 2015. – No. 1. - P. 48-55.
[18] Dzhgamadze A.K., Zaalishvili V.B. Deterioration of groundwater quality due to anthropogenic impact on the territory of Vladikavkaz // Vestnik MANEB. - 2010. - Vol. 15. No.4. - P. 26-31.