Hydrogeochemical features of the North Ossetian artesian basin

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Abstract. The article considers the hydrochemical features of the North Ossetian artesian basin and the changes in its qualitative characteristics over the past 30 years. An increase in the rigidity and, accordingly, mineralization of groundwater in the southeastern part of the Ossetian artesian basin, which occurs against the intensive production background, both directly from the basin and beyond it in the nutrition zone of the aquifer complex is noted. The tendency to increase the rigidity and mineralization of groundwater in the Industrial zone of the Vladikavkaz city has been recorded since 1991, and goes on up to this day. The main version of aquifer pollution is justified by the presence of industrial waste from the plants of “Electrozinc” OJSC and “Pobedit” OJSC, as well as an intensive underground water production from the southeastern part of the North Ossetian artesian basin - about 50 production wells with a capacity of about 1000 m3 / day. Among the many conditions and factors affecting the water chemical composition formation, one of the most important is the active, in most cases, haphazard exploitation of aquifers both within the territory under consideration, in the north-eastern part of the city of Vladikavkaz, as well as outside it, where the recharge comes from the mining level.

Introduction
The studies of deep structure, hazardous geological processes (volcanic activity, glaciers, etc.), their reconstruction and environmental trends have taken one of the leading places in the framework of Earth sciences [1-5]. This is especially true for the environmental hydrogeology, designed to identify, rationally use and protect the most valuable raw material resource and component of the geological environment - groundwater [6]. In North Ossetia, a technologically vulnerable component of the geological environment due to insufficient protection and anthropogenic load are the fresh underground waters of the North Ossetian artesian basin [7].

The North Ossetian artesian basin is a huge reservoir, 25% filled with groundwater. The inflow of river waters and precipitation determines the continuous replenishment of the groundwater operational resources. The only way out of the Ossetian artesian basin for surface and groundwater is the “Elkhotov Gate”, sawn with the river Terek waters in the Sunzhensky (Malo-Kabardinsky) ridge.

Hydrogeological structures of North Ossetia
In hydrogeological terms, the aquifers of the Quaternary formations and Akchagyl Absherov (Ruhszuar Formations) have been sufficiently studied. Of practical interest are the waters of alluvial-
fluvioglacial deposits of the Lower Upper Pleistocene age, which provide the centralized water supply to the settlements located on the Ossetian inclined plain.

The aquifer of modern alluvial sediments (QIV) can be traced in the valleys of rivers and valleys in the form of narrow stripes. Water-bearing rocks are represented by the boulder-pebble deposits with sand aggregate.

The alluvium thickness in the river valleys is from 10 to 40 m (R. Kambileevka, Ardon) to 80-180 m (Terek near Redant). The depth of groundwater varies from 0 to 1-2 m. Natural unloading of groundwater occurs by wedging out in the form of springs or directly into rivers. Alluvial deposits are characterized by significant water mobility (Kf = 25-88 m/day). Fresh water (mineralization of 0.2-0.5 dm3), the chemical composition of magnesium-calcium hydro carbonate. The mining level is of great practical importance.

The aquifer of the lower-upper Quaternary sediments (afQI-III) is widely developed in the plain part of the artesian basin territory. The water-holding is a thick stratum of boulder-gravel-pebble deposits with sand and sand-clay aggregate. The aquifer nutrition over the entire area of the Quaternary sediments’ distribution is carried out due to the infiltration of precipitation and water from surface watercourses. The natural discharge of groundwater from the mining level is carried out into the river network in the form of springs, as well as by the outflow from the basin through the “Elhotovsky Gate”.

The waters of the Quaternary deposits of the North Ossetian artesian basin are the main source of drinking water for the cities of Beslan, Ardon, Digora and other settlements.

The aquifer complex of the Pliocene-Eopleistocene (Akchagyl-Absheron) sediments (N22a-QEap) is distributed on the northern slopes of the Forest Range and then extends a continuous cover under the Quaternary deposits and is exposed on the southern slope of the Sunzhensky Range.

The groundwater of the North Ossetian artesian basin, which is the main source of drinking water for the settlements located within the plain, including the capital of the republic – Vladikavkaz, is not sufficiently protected from pollution due to the absence of seasoned water-resistant layers. There are numerous enterprises of mining, metallurgical and processing industries in the territory. Environmental measures of industrial enterprises do not always meet the environmental requirements, including the territory’s water basin (groundwater, surface watercourses), which may ultimately lead to negative irreversible processes [8-10].

Over the past 30 years, serious qualitative changes have occurred in groundwater in the southeastern part of the North Ossetian artesian basin towards an increase in some chemical components’ content (Fig. 1). These changes are observed in the northern part of the Industrial District of the city of Vladikavkaz, where industrial enterprises, including the metallurgical industry, are concentrated.

According to hydro chemical testing, the quality of groundwater corresponded to the requirements for drinking water. Water hardness was 4-5 mEq / dm3 (normal - 7), and mineralization - 0.5 g / dm3 (normal - up to 1 g / dm3) [10].

In the last 20 years, an increase in water hardness has been noted, which reached 18 mEq / dm3 in individual water intakes, and mineralization reached 1.5 g / dm3 [10]. A trend towards an increase in the groundwater hardness and mineralization has been observed in the Industrial Zone of the city since 1991, and remains to the present (Table 1) [8-11]. The urban areas development involves their active study by modern methods [12-18]. As for other parts of the city, such a drastic change in groundwater quality has not been noted. A halation is highlighted on the schematic map, within which a deterioration in the groundwater quality is recorded (Fig. 1). The table below shows, that the water wells for which an increase in water hardness is systematically observed.

At the Plant borehole water intake, from which drinking water is supplied to the population of the village. According to the results of testing at the end of the production wells’ drilling (1975-1976), the factory (about 25 thousand people) industrial region of Vladikavkaz, the groundwater hardness was maintained within the normal range (7 mEq / dm3) and amounted to 4-5 mg -eq / dm3. Since 1991, water hardness started increasing and, as can be seen from the table, in 2010 it reached 11.0 mEq / dm3.
The same picture is observed for other water intakes of the indicated territory. The maximum value of water hardness is noted for the well No. 250 (LLC “FAT” Agricultural company) - 18.5 mEq / dm³, with water mineralization 1.5 g / dm³ [10].

Figure 1. Schematic geological and hydrogeological map of the northern part of Vladikavkaz. Scale 1:50 000: 1 - alluvial deposits of modern age; 2 - alluvial-fluvio-glacial lower-upper Quaternary deposits; 3 - well: above - number, below - water hardness, mEq / dm³; 4 - subsoil plot with estimated operational DW reserves: a - design water intake for emergency situations in Vladikavkaz No. 2, b - Factory water intake; 5 - a halation of an area with increased groundwater hardness; 6 - surface contour, m; 7 – hydro-isopiezal of the sediments aquifer of the Ruhsdzuar Formation and their absolute elevations, m.

Table 1. Groundwater hardness in the water intake areas of the eastern part of Vladikavkaz

| No. | Departmental affiliation and well number | Testing time, year | Hardness of water, mEq/dm³ |
|-----|----------------------------------------|--------------------|---------------------------|
| 1   | VMUE Vodokanal (Zavodskoy):            |                    |                           |
|     | Well 2                                 | 2009-2010          | 8.9-11.0                  |
|     | Well 4                                 | 2017               | 11.2                      |
| 2   | Ltd «Lux» - Well 6/2                   | 2004-2005          | 7.9-10.3                  |
|     |                                        | 2017               | 12.4                      |
| 3   | OJSC Vladikavkaz brewery “Daryał” - Well 2110 | 2004-2008          | 7.7-9.9                   |
| 4   | Ltd “Forvard” - Well 79                | 2007-2008          | 10.0-11.0                 |
|     |                                        | 2014               | 10.0                      |
| 5   | Company “Ariaana” - Well 1/96          | 2006-2008          | 8.2-8.6                   |
| 6   | Ltd Agricultural company “FAT” - Well 250 | 2006-2009          | 14.7-18.5                 |
|     |                                        | 2014               | 14.4                      |
| 7   | OJSC “Pobedit” - Well 2112             | 2009-2010          | 7.0-8.5                   |
In the southern part of the North Ossetian artesian basin, in the Ruhsdzuar Formation sediments aquifer, over the 20-year period under review, the content (upward) of such components as sulfate, bicarbonate and calcium ions underwent a change. The calcium content increased from 50 (1976) to 136-174 (2009) mg / dm³, sulfate from 17-40 mg / dm³ to 91-169 mg / dm³, chloride - from 7-10 to 28-60 mg / dm³. The hydro carbonate content also increased significantly - up to 262-364 mg / dm³ [7, 8].

**The results’ discussion**

With regard to the ongoing changes in the groundwater quality in the southeastern part of the North Ossetian artesian basin, the version of pollution of the aquifer by industrial waste from the plants “Electrozinc” OJSC and “Pobedit” OJSC seems quite significant. For more than a hundred years, industrial wastes of these enterprises have been disposed at the dump sites of factories in the northern part of the Vladikavkaz city. The dumps contain the elements related to various hazard classes, including and to the first, in particular, lead, zinc, cadmium, etc. The entry of these elements into the aquifer cannot be considered as simple pollution of the geological environment. This contributes to a change in the groundwater chemical composition not only due to the introduction of accidental components, but also to the changes in the physical and chemical processes during their migration in the aeration zone and in a water-saturated environment. Schematically, this process can be represented as follows: acidified with sulfuric acid (sulfide ore processing products are located on dump fields), storm waters flow down the surface and, seeping into the soil, enhance the carbonate and other rocks dissolution, thereby increasing the content of calcium and magnesium ions in water silicon [8].

The change in the groundwater quality in the southeastern part of the artesian basin occurs against the background of the groundwater intensive extraction, both directly from the pool and beyond - in the nutrition zone of the aquifer, where from the south along the extended floodplain of the river. Terek from the Darial Gorge into the plain rushes a powerful stream of surface and groundwater. At the same time, alluvial-fluvioglacial deposits are anhydrous at the exit from the Darial Gorge, north of the Redantskaya deepened valley, and an infiltration of a significant part of the river water supplying the aquifers of the artesian basin occurs here. Thus, the surface runoff of the Terek River, and the groundwater flow coming from the Redantskaya deepened valley, to which the Ordzhonikidze groundwater field is located, supplying the city of Vladikavkaz, are largely involved in recharging the first from the surface of the aquifer sediments of the Ruhszuar Formation in the southeastern eastern part of the Suvurs-Ossetian artesian pool [7].

The productivity of the Redant water intake systematically exceeds the approved reserves (250 thousand instead of 210 thousand m³ / day). Perhaps for this reason, in the same 30 years, an inadequate decrease in the water level of the operational aquifer and the mudding of water-bearing rocks occur at the field. This led to the underflow waters’ level separation from the Terek river bed at the water intake sites and the spread of the depression funnel on such a scale that the Redant springs did not function for several years, apparently due to the interception of part of the spring runoff by the Redant downhole water intake.

The Ordzhonikidze freshwater deposit itself is located above the Redant sulfide water deposit. The sulfide water zone here begins with a depth of about 200 m. Their exit to the surface is hindered by a low piezometric level (not more than 10 m), as well as a fresh water zone in the upper part of the Tithonian sediment section. With a decrease in the power of the latter due to the pressures discharge, as well as an increase in the role of fresh waters of the Tithonian deposits in the formation of groundwater resources, it is possible that deep hydrogen sulfide waters are being pulled to the surface. The depth of production wells of the Redant water intake is about 80 m, and the thickness of the aquifer reaches 140 m. Accordingly, the active drainage zone reaches a depth of 8 m when surface runoff is infiltrated, and the waters enriched in hydrogen sulfide due to the inflow from the underlying aquiferous complex of mineral waters from the interval 80–140 m below the active exploitation zone,
they enter the loose rocks through the Maykop water-resistant clays, forming an aquiferous sediments complex of the Ruhszuar (Akchagyl-Absheron) sediments in the south of the artesian basin. It can be assumed that the unsystematic exploitation of the Ordzhonikidze field provokes the pulling up of hydrogen sulfide waters in the upper zones, where they are mixed and outflow is directed towards the rukhszuar deposits aquifer complex formation in the North Ossetian artesian basin. This process is quite common, especially in the valleys of large rivers, and occurs in aquifers at different depths. In the case under consideration, a mixture of mineral and fresh waters can be assumed, as a result of which the ion composition of fresh waters changes and poorly soluble substances precipitate from them - calcium sulfates and carbonates.

One of the reasons for the ongoing process can be suggested by the following factor. On the above-mentioned area, in the industrial zone of Vladikavkaz, about 50 production wells with a productivity of about 1000 m3/day each are concentrated and operate. With such intensive extraction of groundwater from the Ruhszuar aquifer complex with relatively low water mobility, a progressive decrease in the productive aquifer level occurs, which causes the pullback of groundwater with an increased salt content from the underlying layers.

Thus, among the numerous conditions and factors affecting the water chemical composition formation, one of the most important is the active, in most cases, unsystematic exploitation of aquifers both within the considered territory, in the northeastern part of the Vladikavkaz city, and also beyond it, from which point the mining level comes from.

Summary
The final solution to the issue of identifying the causes of what is happening and taking the appropriate measures in the south-eastern part of the North Ossetian artesian basin is possible according to the following results:

a) conducting specialized environmental, hydrogeological and hydrogeological surveys at industrial waste disposal sites of plants “Electrozinc” OJSC and “Pobedit” OJSC;

b) conducting the hydrogeological studies on the Ordzhonikidze groundwater field with a reassessment of operational reserves and the development of a rational scheme for the field operation;

c) organization of groundwater monitoring within the Ossetian artesian basin for all the existing well intakes.

References
[1] Shempelev A, Zaalishvili V, Kukhmazov S 2017 Geotectonics 51(5) 479-488.
[2] Zaalishvili V, Melkov D, Dzeranob V, Morozov F, Tuaev G 2018 International Journal of GEOMATE 15(47) 158-163.
[3] Milyukov V, Yushkin V, Kopaev A, Mironov A, Dem’yanov G, Sermyagin R, Basmanov A, Popad’Ev V, Nasretdinov I, Zaalishvili V, Kanukov A, Dzeranob V 2014 Measurement Techniques 56(10) 1105-1110.
[4] Zaalishvili V, Nevskaya N, Nevskii L, Shempelev A 2015 Journal of Volcanology and Seismology 9(5) 333-338.
[5] Zaalishvili V, Melkov D 2014 Izvestiya. Physics of the Solid Earth 50(5) 707-718.
[6] Zaalishvili V, Dzhgamadze A, Gogichev R, Dzeranob V, Burdzieva O 2018 International Journal of GEOMATE 15(51) 22-30.
[7] Jghamadze A 2010 Report on the results of exploration of the Zavodsky site (Vladikavkaz) with the calculation of underground fresh water reserves as of 01.07.2010 146.
[8] Pashchenko A, Dzhgamadze A 2006 Report on the results of the exploration of the groundwater section operated by Pobedit OJSC, with reserves calculated as of 01.08.2010 123.
[9] Dzhgamadze A 2006 Report on the results of hydrogeological studies with an assessment of the operational reserves of groundwater in the northwestern part of the Industrial District of Vladikavkaz by autonomous operational sites: LLC Totos, OJSC Vladikavkaz brewery Daryal and LLC Vladikavkaz Food Processing Plant of the Sevospotrebsoyuz of July 1, 2005 145.
[10] Pashchenko V. 2007 Report on the results of hydrogeological studies in the subsoil area provided Agricultural company FAT LLC (Vladikavkaz, North Ossetia-Alania), with the calculation of the operational reserves of groundwater as of 10.07.2007 136.

[11] Burdzieva O, Zaalishvili V, Beriev O, Kanukov A, Maisuradze M 2016 International Journal of GEOMATE 10(1) 1693-1697.

[12] Zaalishvili V, Kanukov A, Melkov D, Makiev V, Dzobelova L 2018 International Journal of GEOMATE 15(51) 160-166.

[13] Grigorkina G, Ramonova A, Kibizov D, Kozyrev E, Zaalishvili V, Magkoev T, Fukutani K 2017 Solid State Communications 257 16-19.

[14] Zaalishvili V, Melkov D, Kanukov A, Dzeranov B, Shepelev V 2016 International Journal of GEOMATE 10(1) 1670-1674.

[15] Zaalishvili V, Melkov D, Kanukov A, Dzeranov B 2016 International Journal of GEOMATE 10(1) 1656-1661.

[16] Zaalishvili V 2016 Measurement Techniques 58(12) 1297-1303.

[17] Zaalishvili V, Nevskaya N, Melkov D 2014 Izvestiya. Physics of the Solid Earth 50(2) 263-272.

[18] Zaalishvili V, Melkov D, Kanukov A 2019 Akustika 32 279-283.