Opportunities for the drinking water resources’ export-oriented commercialization as a potential element of the economic framework in mountainous areas

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Abstract. The predicted reserves of fresh groundwater in the Kabardino-Balkarian Republic (KBR) reach 7200 thousand m³/day, which is 31.2% of similar resources in the North Caucasus Federal District, ranking first in the region. In terms of mineralization in general, groundwater in the KBR belongs to the class of “fresh groundwater”; in terms of chemical composition they are classified as “drinking”; in terms of total hardness - to “moderately hard water”. Water does not contain significant concentrations of heavy metals and inorganic nitrogen compounds. However, the use of the indicated potential is limited only to the creation of local lines for bottling water with a small capacity, mainly focused on the republican and regional markets of Russia. The purpose of this study is to substantiate the hypothesis about the sufficient resources’ availability of hydrogeological materials suitable for industrial production and bottling as ecologically clean drinking water. Within the framework of the designated goal, the following tasks were solved:
- search for mountain landscapes, in the first approximation localizing the balance reserves of fresh groundwater;
- environmental monitoring of the sites previously designated as favorable for the drinking water extraction;
- the productive aquifers’ assessment nature and the conditions of their natural protection from pollution;
- identification of natural components that maintain the balance of groundwater and factors of its change over time;
- establishing the specifics of groundwater discharge and the dynamics of regime-forming processes in the vertical zoning conditions in the study area.

Introduction
The provision of the world’s population with high-quality drinking water is recognized as an important condition for the high life expectancy of people, in connection with which the demand for bottled drinking water is steadily increasing. The latter has become the most important product of industry and world trade.
Assessing the chances of the republic’s participation in the international division of labor in the sphere of drinking water circulation, it should be noted that the predicted potential of underground drinking water is 18 times higher than needed in KBR. 28 deposits of underground drinking sources with balance reserves of 1041 have been tested thousand m³/day in Kaburdino-Balkaria. The content of normalized components in them in the overwhelming majority of deposits is within the Russian standards and regulations’ requirements, as well as the European standards according to WHO. At the same time, only 15% of the reserves of the explored part of groundwater resources have passed the state examination. The share of underground sources in the structure of drinking water use does not exceed 7-8%, which indicates a weak degree of their involvement (Figure 1).

Meanwhile, having significant opportunities for export-oriented industrial bottling of ecologically clean drinking water of the highest quality, the republic is practically not involved in the process of the current dynamic distribution of the formed markets for its sales.

Results
Stimulated by the dynamic development of the soft drink industry giants, relatively low capital costs for organizing production, the natural balance of the reserves volume and the groundwater chemical composition, the potential budgetary price for products, Kabardino-Balkaria may also have a strong chance of entering this market.

A comparative characteristic (Table 1) of the chemical composition of some bottled drinking water bottled in a number of European countries and Kabardino-Balkaria is presented below.

![Figure 1. Structure of fresh water consumed in Kabardino-Balkaria by sources](image)

Table 1 shows that the maximum permissible concentrations (MPC) of chemical elements in different countries differ significantly. At the same time, KBR bottled drinking water do not exceed the upper limits of chemical compounds’ permissible concentrations than the quality indicators of the high-quality imported analogues. According to the solid residual, “Crystal Valley”, for example, is several times less saturated with the dissolved inorganic and organic substances than a number of well-known brands. The fact of the high-quality republican water products is confirmed by the certificates of the relevant services of the World Health Organization (WHO), the experts from the Bodicoal laboratory (Great Britain). According to their data, drinking water “Bezengi”, “Azau”, “Elbrus”, “Vertical”, “Crystal Valley” are...
chemically and microbiologically flawless and comply with the Codex of Hygienic Practice for Bottled or Packaged Drinking Water Bottled / Packaged Drinking Water), as well as the Russian SanPIN 10-113 RB 99. The initial mineralization of the base underground basins of the drinking water listed brands does not exceed 01-0,3 g/dm³. This water has a composition and physical characteristics that are favorable for the human body and do not require chemical water treatment, with the exception of aeration, filtration, etc.

With a view to the export-oriented commercialization of drinking water use in KBR the authors have identified a number of presumably promising mountain areas within the Baksan, Irik, Adyl-Su, Malka, Zhapyr-Tala, Karasu, Kurkuzhin tracts using large-scale hydrogeological maps. Within their limits, a field sanitary and hydrogeological survey has been carried out:
- the actual sanitary and ecological state (for May 2020) of the proposed areas for the operational reserves’ formation;
- the groundwater natural protection level from external pollution.

It was revealed that the natural elements feeding groundwater are natural precipitation, melted glacial and partly surface water, from which it follows that the deposits are of exclusively infiltration origin. Moreover, the ratio of the elements feeding the deposit is noticeably corrected in space and time.

The mineral composition of groundwater in the designated areas is determined by their hydrogeological structures: the rocks’ composition, the deposits’ depth and the unloading water’ migration nature. The latter circulates in veins and fissures of Proterozoic crystalline rocks (shales, gneisses, quartzites, etc.), often broken by granite intrusions, which are widespread in the geology of high-altitude levels within 4 thousand meters (Figure 2). Taking into account the low solubility of crystalline rocks, it can be predicted with a high probability that the water in the indicated cavities are weakly mineralized. Consequently, the substances dissolved in water will have an infiltration genesis, from which it follows that the predominant glacial feeding of most deposits should limit the downward components’ migration of anthropogenic origin [1].

**Table 1. Characterization of the chemical composition of some bottled drinking water**

| Indicators quality, mg/l | Category of high-quality drinking water | Azau (KBR) | Crystal valley (KBR) | Standards quality water by WHO | Council directive EC № 80/778 |
|--------------------------|----------------------------------------|------------|---------------------|--------------------------------|-----------------------------|
| Misia (Italy)            | Valvert (Belgium)                      | Catharina (Netherlands) | Crisitroc (France) | Highland Spring (Scotland) | Thonon (Switzerland)         | 80-120                       | 152.5 | — | 30-400 |
| pH                      | —                                     | 7.6        | 7.8                 | 7.2-7.4                       | 7.5                          | 6.5-8.5                      | 6.5-9.5 |
| Solid residual          | 216.8                                 | 201        | 160                 | 223                           | 136                          | 342                          | 200-310 | 8.0 | 1000   | 1500 |
| Mineralization          | 314                                   | 302        | 212                 | 320                           | 200                          | 509                          | <500   | 285.1 | —      | 200-500 |
| HCO₃                    | 202.1                                 | 204        | 147                 | 195                           | 136                          | 350                          | 80-120 | 152.5 | —      | 30-400  |
| SO₄                     | 20.39                                 | 18         | 1.9                 | 21                            | 6                            | 13                           | 40-70  | 16.9  | 250    | 250 |
| Cl                      | 6.71                                  | 4          | 7.4                 | 11                            | 7.5                          | 9                            | 5-10   | 5.2   | 250    | 250 |
| NO₃                     | 1.73                                  | 4          | 0.4                 | <1                            | <1                           | 12                           | <5     | <5    | 50     | 50 |
| Ca                      | 68.93                                 | 67.6       | 42.4                | 70                            | 35                           | 108                          | 25-50  | 60    | —      | — |
| Mg                      | 4.01                                  | 2          | 2.8                 | 3                             | 8.5                          | 14                           | 4-12   | 6.7   | —      | 50 |
| Na                      | 3.51                                  | 1.9        | 9.66                | 4.8                           | 6                            | 3                            | 1-30   | <20   | —      | — |
| K                       | 0.55                                  | 0.7        | 0.5                 | 1.4                           | 0.6                          | <1                           | 1-45   | 3.2   | —      | 2-20 |
Figure 2. Schematic map of fresh water deposits presumably suitable for industrial bottling

A more significant problem of involving vein-fissured groundwater in drinking water use is mainly the local watering of ecologically clean high-altitude areas. The exception is the relatively large deposits within the catchment areas of the Malka, Karasu, Kurkuzhin rivers, the localization of which has a basin character.

The low forward ridges of the Greater Caucasus are predominantly composed of soluble Jurassic limestones. Judging by the nature of the numerous springs’ discharge and their chemical composition, free-flow underground water horizons with a small thickness of the aeration zone are localized here [2]. Confirmation of this hypothesis is the constant of the drinking water quality, which will allow, if it is involved in nature management, to switch from the purification of produced water to their pollution prevention. Therefore, for example, the water of the Kara-Su spring in the basin of the Cherek River can be packaged in their natural state without preliminary water treatment, except for the need to comply with strict sanitary-preventive measures during their intake and bottling. This water is not only harmless, but biologically valuable and retains high consumer properties.

The underground water of the Ciscaucasia can be represented by an artesian basin with the reservoir-type water accumulations in significantly dislocated and lithified terrigenous-carbonate complexes. Even lower are the layers of sedimentary rocks of the North Jurassic depression, which, together with aquifers, are submerged under the cover of younger layers, creating a significant head of high-quality hydro-carbonate calcium water [3]. The increased content of hydro-carbonates in the component composition of the Ciscaucasia underground water predetermined their weak mineralization. This feature is associated with the fact that limestones represent an active sorption barrier that reduces and neutralizes the pollution migrating inward. Consequently, groundwater with such protection represents an unfavorable environment for the accumulation of standardized micro components and is epidemiologically safe.

In the course of this study, an assessment of the current character of groundwater discharge has been carried out. The water content of the hydrogeological folded region in Central Caucasus is due to the weathering crust of crystalline rocks. At the depths from 60 to 100 m, the fault zones have been formed,
penetrating into the body of the hydrogeological massif. Within the carbonate karst strata, open discharge of the basins in the form of springs with a flow rate of up to several hundred liters per second prevails. Intrusive and metamorphic massifs are naturally less water-abundant, since fresh water circulates in a limited space of fractured and fractured-vein horizons [4].

Groundwater within river valleys is fed from the subaerial springs, including precipitation through the accelerated infiltration of alluvial deposits. The aquifers here are often not overlapped and not underlain by mature, low-permeable sediments, therefore, their natural protection is insufficient. For water springs which depth is less than 5 m, the risks of increased mineralization are higher. The indicated hydrodynamic horizon is a zone of free water exchange, due to which groundwater is directly affected by the modern climatic dynamics and is drained by the mountain rivers. Therefore, the salinity of the horizon water is likely to vary within 1 g/l, which meets the quality requirements for water for centralized water supply. At the same time, this aquifer has a large safety margin in terms of uninterrupted drinking water supply due to the high infiltration parameters of pebbles, sands and sandy loam formations above the floodplain terraces. However, the high productivity of these basins dictates the need for systematic hydrogeochemical studies of bottom sediments, soils, snow throughout the water reserves formation area [3].

The groundwater operational resources’ calculation can be made according to the formula [5]:

\[
Q = \frac{2VKHS}{\ln R - \ln r}
\]

Where \( Q \) – is water intake capacity, m³/day;
\( V \) – is volumetric fluid loss;
\( K \) – defines the rock filtration coefficient, m/day;
\( H \) – is the thickness of flooded rocks, m;
\( S \) – denotes the level lowering, m;
\( R \) – is the influence radius, m;
\( r \) – is the well radius, m.

After the groundwater basins’ potential productivity calculation, it is possible to proceed to the specific locations’ substantiation for the production wells. It is advisable to draw up a water intake scheme with grid steps that ensure a stable water resources’ flow rate. In the presence of extensive complex groundwater recharge, as, for example, in the subniveal zone, the volume of water withdrawal in the autumn-summer period is practically not limited. In the areas with low infiltration capacity of horizons, the drainage size should be controlled. The dependence of the well flow rate on the groundwater level lowering is shown in Figure 1.

Figure 3 makes it possible to judge the well productivity dynamics at different lowering of the groundwater level. The presented graphs allow to determine the limit of the permissible level lowering for the stable obtaining of the given flow rate with free-flow and pressure water. \( 1/3 \) thickness of the watered strata, at which the consumer can count on 95% stability of the field’s fluid loss can be taken as the value of the limiting water level lowering from its initial indicator in the pool.

The final stage of the work was the recording of the actual ecological state of the promising areas, drawing on the topographic map of all the detected water manifestations (springs), identifying the potential channels for possible groundwater pollution. Thus, in the process of field studies of the upper reaches in the Malka River, early drilled but abandoned wells that were used for distant pasture farming and for milk processing in the mountains, have been discovered. Sluggish contamination of groundwater can occur through the unsealed wellbores [2].

The potential of mountain springs is practically not used. Most of them have not been studied, their cadastral registration has not been conducted, the qualitative characteristics of the sources have not been studied, the exit places are not recorded on the topographic map. The applied value of the springs is limited only by the occasional use of some unsettled sources in tourism.
**Figure 3.** Graph of the well flow rate dependence from water level lowering

Meanwhile, a number of springs with the current production rate can become a self-sufficient source of water supply to the mountain settlements, which have not yet been provided with drinking water reliably protected from pollution. Mountain-folded areas are characterized by good washing, dense fracturing, in the middle mountains - karst, therefore the springs have a quite acceptable level of mineralization [2]. However, before a decision is made to fill the water supply network with them, it is necessary to establish the observation of candidate springs for involvement for several years to identify the size of their minimum discharge in a dry season. The springs with discharge less 10 l/s cannot supply water networks without interruption. In this case, the minimum flow rate ratio to its maximum level should be in the ratio 1:2. This type of discharge allows the spring to be classified as a permanent water source [5].

The current geography of fresh groundwater distribution and the nature of their mineralization can be corrected by post volcanic carbon dioxide migrating in the form of a solution from the Elbrus magma chamber. Therefore, in the short term, isotopic studies of surface and ground water should be included in the general complex of prospecting works to assess the nature and intensity of water exchange [1].

The appraisal work should be completed by the pilot-filtration testing of deposits, determination of the estimated production rate of wells, analysis of all significant groundwater basins’ quality in accordance with the international standards. But for this complex of works, a potential subsoil user should obtain a state license (permission for geological subsoil study).

**Summary**

The underground water of the mountainous zone of Kabardino-Balkaria are represented by the locally watered vein-fissure, bed-block and cover-flow deposits. The most significant of them can be considered 13 deposits not involved in water use with total forecast reserves in 144 thous. m³/day. Judging by the chemical composition of the springs associated with a number of these deposits, the level of mineralization in none of the flooded areas does not exceed 1 g/dm³.

Due to the overcrowding of unused underground storage facilities, tens of thousands of cubic meters of fresh water, in particular, especially valuable melted ice water, irretrievably flows into the sea every day. In the conditions of the republic’s truncated tax base and extremely low incomes of the population, this is an impermissible luxury.

Meanwhile, this sphere of nature management can become an important element of the ecological and economic zone’s design in the mountains of the KBR, proposed by the authors. The revealed regularities of the space-time dynamics of groundwater made it possible to outline the specific areas for the commercialization of drinking water use. The described potential is a serious reserve for Kabardino-
Balkaria to acquire the status of a reliable exporter of drinking water in world economic relations. To do this, it is necessary to create a network of bottling plants with a modern production infrastructure. The motives for the users activating potential subsoil should be relatively low capital costs for organizing production; rather high profitability of the enterprises producing, bottling and selling drinking water; the prospect of an ever-increasing demand for high-quality drinking water.

At the stage of entering the world drinking water market, the main task of the aquatic products’ manufacturers should not be to maximize profits, but to persistently build the trust of domestic and foreign consumers, as well as loyalty of control and regulatory bodies in republican brands. In case of water use controlled commercialization civilized organization from the point of view of preventing the new property redistribution in the mountains and entrepreneurial selfishness, the brand of drinking water of Kabardino-Balkaria can take a stable place in the world market of soft drinks.

Acknowledgements
The study was carried out with the financial support of the Russian Foundation for Basic Research within the framework of a scientific project № 19-010-00882.

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