ASSESSMENT OF THE POLLUTION PROBABILITY IN BORJOMI-BAKURIANI AREA BY APPLICATION OF HYDROCHEMICAL AND STABLE ISOTOPE METHODS

GEORGE I. MELIKADZE
Institute of Earth Sciences, Ilia State University

Borjomi field of thermal water is a source of famous mineral water, which is exported to dozens of countries and forms a significant part of the budget of Georgia. Recently, in connection with the construction of the Baku-Tbilisi-Jeikhan pipeline, serious concerns arise with respect to vulnerability of water supply of the city of Borjomi caused by possible oil spills related to the operation of the pipeline. In the paper, we consider mainly the interaction between surface water and groundwater of the Bakuriani-Borjomi lava flow and the possibility of their pollution with hydrocarbons in the case of oil spilling. In order to define the possible pollution propagation, we apply hydro-chemical methods, stable isotope technology and other modern hydro-geophysical methods, which were adequate for better understanding of existing hydrogeological models, parameters and the risk of pollution is evaluated.

Keywords: Stable isotope, pipeline

1. Introduction

The section of the Tbilisi-Baku-Ceykhan (TBC) pipeline, situated on the southern periphery of the village Tsikhisjvari, is about 0.5 kilometres apart of the stripe where the Quaternary lava formation outcrops to the surface. This is the recharge area for the breccias aquifer formation, which underlay the lava formation. The precipitated surface waters are released in the form of a group of large springs in the areas of the villages Sadgeri, Daba and Tsemi. The resort Borjomi is mainly supplied with water from the large spring situated on the right part of the deep and narrow gorge of the river Borjomula in about 7 km from the center of the resort. The local name of the spring is "Tsisqvilis Tskaro" (the mill spring) and it is also called "Sadgeri spring".

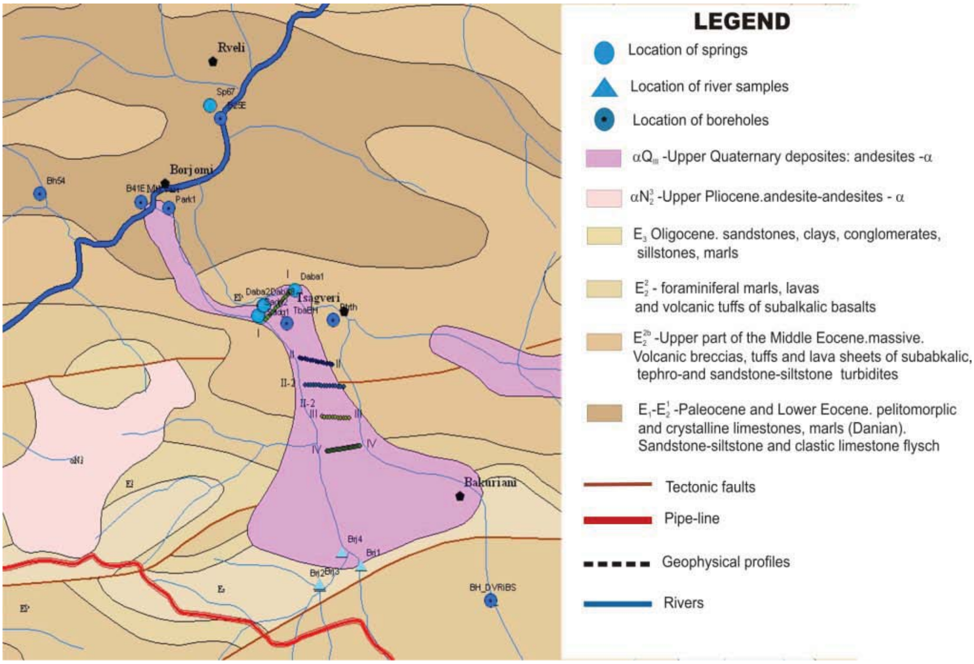

Fig. 1 Geological map of study area

The earlier data of the electric prospecting shows that the main water flow under the lava takes place 180 m below the surface, within the early Quaternary alluvial sediments of the paleo-channel of the river Borjomula. Two opinions are suggested in connection with environmental situation of this area in case of oil spill from the TBC pipeline. According to the first model, presented by expert of PB, Professor J. Lloid (Lloid et al., 2002), part of the water, infiltrated into the andesite-basalt lavas, is naturally discharged in the Borjomula, Gujareti and Tsemula river-beds and its outflows are on the slopes of river gorges, as shown on the diagram (Fig.2), i.e. spring water will not be polluted in case of oil spill.. The second model, presented by Prof. of Georgian Technical University U. Zviadadze (Zviadadze et al., 2002)), however, asserts that the bulk of the infiltrated water that moves further down and reaches the waterproof layer (in this case the Upper Oligocene - Lower Miocene clay layer) and then moves towards the large Borjomula-Gujareti interfluves sheet, which means that oil pollution will reach drinking water source (Sadgeri spring).

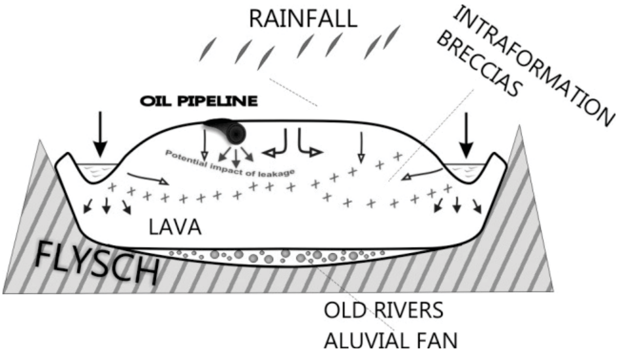

Fig. 2 Conceptual model

2. Data Analyses

In order to study the possibility of spoiling of drinking water in Borjomi area, the International Agency of Atomic Energy (IAEA) delivered the grant to Mikheil Nodia Institute of Geophysics. The main objectives of the project were to developed a conceptual model of water flows in the target area, with special focus on the interactions of the rivers and mineral springs with the surrounding aquifers; using nuclear technologies (natural isotopes) and hydro-chemical methods in selected areas for investigation of the recharge and discharge areas of the groundwater and possible propagation directions of pollution; and organizing a monitoring system against possible drinking water pollution.

2.1. Stable isotope and hydrochemical sampling

With a purpose of investigation of pollution's transfer possibility by water flows hydrochemical compounds of all hydrogeological formations and their connection in the region have been studied, namely: i. the mineral water of Eocene-Paleocene flysch formation (5 boreholes), ii. fresh waters (5 springs and 1 boreholes), iii. waters of lava formation and surface waters/rivers (5 sampling points). Totally, sixteen sampling points have been selected within the study area to collect information on chemical and isotopic composition of water.

From May 2007 till November 2009 ten sampling campaigns have been carried out. The main hydrochemical macro- and microcomponents of water sources have been tested by the field hydrochemical laboratory (Multi-340i/SET and Spectroquant®Colorimeters), which also have been purchased by the IAEA. Stable (^{2}H and ^{18}O) isotopes and tritium content have been measured in the several laboratories of Europe (Austria, Poland, Slovakia etc).

2.1.1. Hydrogeochemistry

Results were analyzed by AquaChem computer program. All water types were analyzed separately (Fig.3). Mineral water from boreholes №54, №41, №1, №25 in Borjomi belongs to sodium-carbonate type (Fig.4) with a high level of total dissolved solids (TDS).

Springs by composition (Fig. 5) are richer in magnesium that also points to the groundwater flow in contact with lava bodies along a way of water movement from lava flows .

In conclusion we can summarize that there are three groups of water by chemical composition: 1st group of mineral water, 2nd group of fresh water from the rivers and the last one from the springs, which is genetically connected with the second group.

2.2.2 Isotope data

Isotopic composition of water measured in eighteen sampling sites of the study area is presented in the Table1.

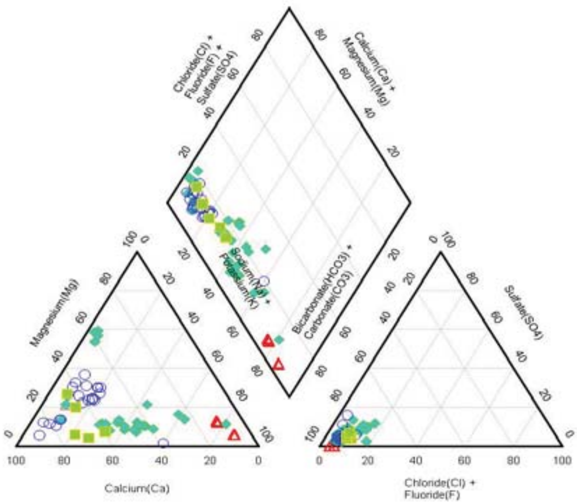

Fig. 3 All water groups

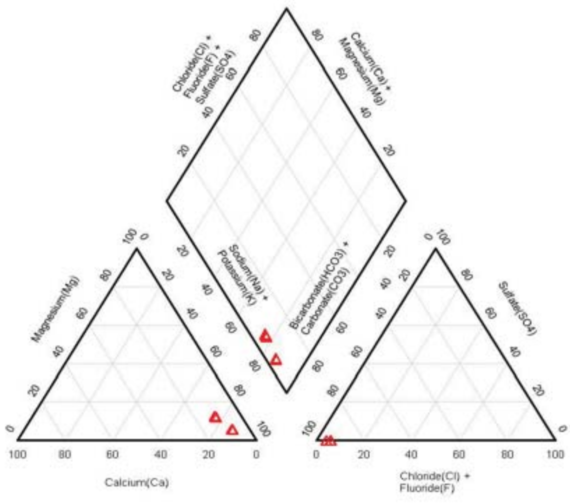

Fig. 4 Summary plot of chemical composition for all mineral waters

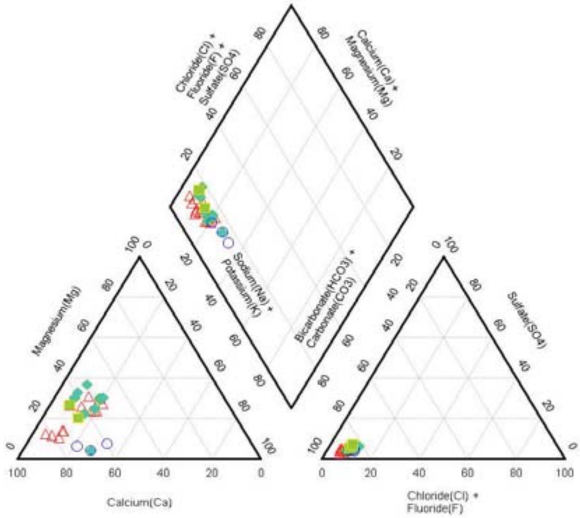

Fig. 5 Groups of all springs

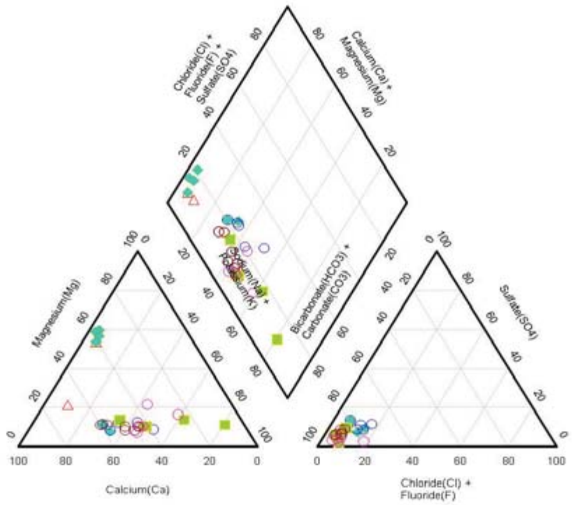

Fig. 6 Groups of all rivers

Table 1. Isotopic composition of water.

No.	**Sampling site**	**$\delta^{18}O$*)** **(‰)**	**δ^2H*)** **(‰)**	**d-excess**)** **(‰)**	**Tritium**)** **(TU)**
1	Borjomi Park	-13.30 ± 0.05	-98.5 ± 1.1	7.9 ± 0.5	< 1
2	Daba 0 spring	-11.52 ± 0.03	-79.8 ± 1.1	12.4 ± 0.5	8.7 ± 1.2
3	Daba 1 spring	-11.56 ± 0.09	-80.5 ± 1.5	12.0 ± 0.5	10.5 ± 1.9
4	Daba 3 spring	-11.48 ± 0.09	-80.5 ± 1.6	11.3 ± 0.6	11.1 ± 2.2
5	Bakuriani Didi Veli	-13.54 ± 0.13	-92.5 ± 1.2	15.8 ± 0.5	< 1
6	Bakurianischali	-11.58 ± 0.22	-78.1 ± 1.7	14.5 ± 0.5	13.1 ± 1.9
7	Borjomula river	-11.20 ± 0.20	-77.6 ± 1.4	12.0 ± 0.7	13.6 ±
8	Borjomula river	-11.39 ± 0.32	-77.5 ± 1.5	13.6 ± 0.8	12.4 ± 1.9
9	Borjomula river	-11.33 ± 0.29	-77.5 ± 2.1	13.4 ± 0.6	16.6 ± 1.1
10	Borjomula river –	-11.39 ± 0.23	-78.1 ± 1.7	13.0 ± 1.1	15.2 ± 1.4
11	Tba borehole	-11.54 ± 0.35	-81.2 ± 1.4	11.2 ± 0.7	9.2 ± 0.9
12	Spring near borehole	-11.38 ± 0.18	-79.6 ± 1.4	11.4 ± 0.2	13.2 ±
13	Borjomi 25e	-12.62 ± 0.09	-99.8 ± 0.8	1.2 ± 0.4	< 1
14	Borjomi 41e	-13.20 ± 0.11	-99.4 ± 0.8	6.1 ± 0.9	< 1
15	Likani 54 borehole	-14.05 ± 0.06	-103.9 ± 1.1	8.5 ± 0.5	< 1
16	Sadgeri spring	-11.71 ± 0.15	-80.9 ± 2.1	12.8 ± 0.7	9.3 ± 0.9

The δ^2H - $\delta^{18}O$ relationship (Fig. 8) reveals several distinct features of the sampled waters. All collected river samples (Borjomula river and its three branches, Bakurianischali river) form a tight cluster of points located above the GMWL.

River and spring samples reveal generally high, although quite variable tritium concentrations. Average tritium content in river samples is equal to 14.3 ± 0.9 TU (Tritium Unit- it means there are 14.3 atoms of tritium per 18atoms of hydrogen). For springs (Daba 0, 1 and 3; Sadgeri spring) the average tritium content is significantly smaller (9.9 ± 0.5 TU). The deep boreholes most probably do not contain any tritium, although the reported data scatter considerably.

Somewhat lower tritium value in springs compared to rivers, combined with slightly lower $\delta^{18}O$ and δ^2H values and might indicate the presence of additional water component, recharged at higher elevation and with longer mean transit time of water to the springs.

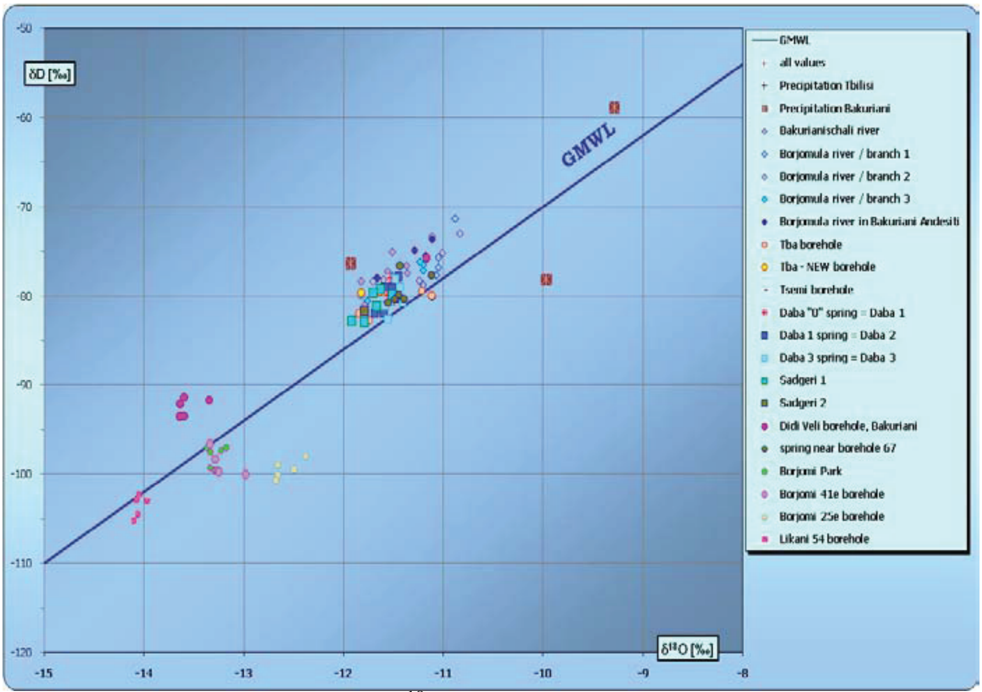

Fig. 7 All data: $\delta^{18}O$ [‰] & δD [‰] vs SMOW

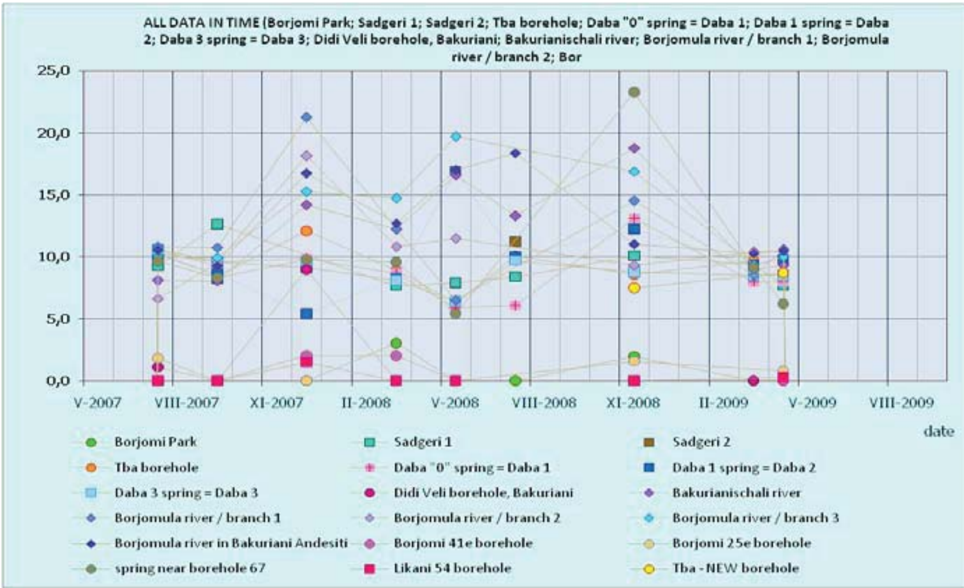

Fig. 8 All data: ^{3}H [TU] vs. TIME

2.2. Organization of monitoring with warning system in the areas of possible pollution

In the areas of potential pollution, namely, in the recharge, stream flow and discharge areas three devices of special monitoring equipment "SEBA" have been installed. Water level, temperature and electric conductivity are observed regularly at these sites. Multi-parameter measurements are conducted at 15 or 30-minite time-intervals. In order to organize alarm-system, data are transmitted and accumulated in the real time mode with requested frequency to the central laboratory. The data are connected to other monitoring results. As a result, the regime-defining factors of groundwater (seasonal and diurnal variations etc) as well as amplitudes of possible variations were ascertained.

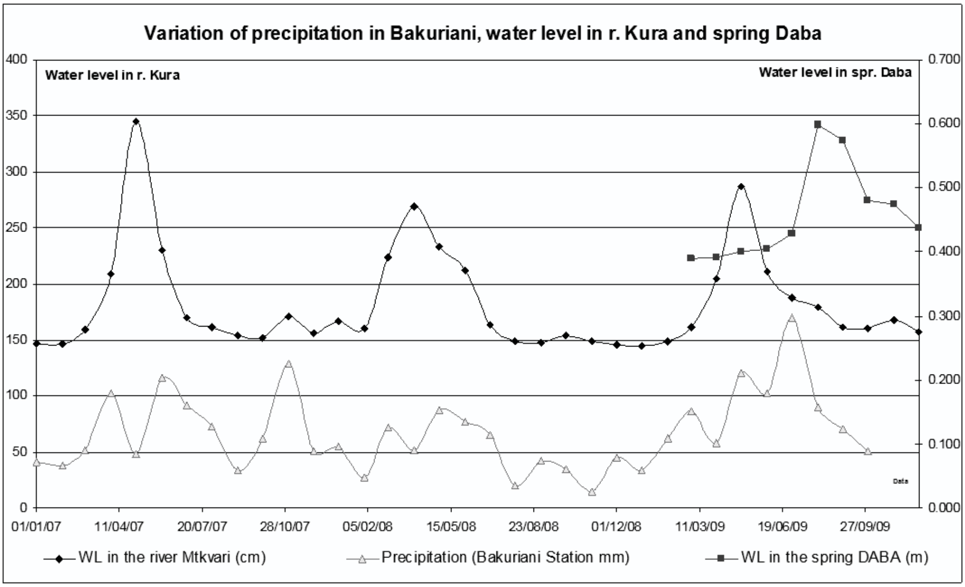

Fig. 9 Variation of precipitation in Bakuriani and water level in Daba spring and river Kura (nearby Likani station).

We compared and analyzed all data which were collected during observation on the monitoring stations. Seasonal variation in the river Mtkvari and Daba spring is fixed, which is related to precipitation in

Borjomi-Bakuriani area, but the maximum of seasonal variation in the Daba spring appears later than in river. It means that the pathway of water from recharge area to spring discharge area is longer (by 30-40 days) than the pathway to the river. In future, this system may help to fix and inform us on the rate of pollution propagation in the aquifer after oil spill.

3. Conclusions and recommendations

According to geological, hydrogeological, hydrogeochemical, isotope and other investigations, carried out in the Borjomi-Bakuriani test area we conclude that the waters of rivers Borjomula and Gudjaretis-tskali are formed simultaneously in the same recharge area, namely, Bakuriani-Tsikhisjvari lava plateau. After infiltration into the lava sheet “spring water” flows along ancient river valley in Quaternary alluvial formation and is discharged at Sadgeri and Daba springs.

This is confirmed by isotope data: the stable isotope data presented above reveal that Sadgeri spring, which supplies the Borjomi resort with potable water, as well as Daba springs, carry essentially fresh water, isotopically and chemically similar to that of Borjomula river and Tba borehole drilled in the lava bed. Stable isotope data also suggest that all springs mentioned above contain additional water component, recharged at higher elevation, with longer mean transit time to the discharge points. This hypothesis is supported by significantly lower tritium content in springs compared to rivers.

Water flows along breccia rocks and that is why their pathway to surface is longer than the route of waters flowing to rivers. This opinion is confirmed by chemical data: the springs’ waters are richer in magnesium than river waters.

By monitoring data, it has been found that the maximum of seasonal variation in the Daba spring is fixed later (30-40 days) than in river Mtkvari. It means that the pathway of water from recharge area to spring discharge area is longer than the pathway to the river.

Thus the possibility of Borjomi city drinking water pollution in case of pipeline accident is very realistic and corresponds to the model of Prof. Zviadadze. In this connexion it is necessary to take effective measures for protection of water source areas.

Acknowledgements

Author acknowledges support of International Atomic Energy Agency # GEO8003 "Using Isotope Techniques to Assess Water Resources in Georgia"

4. References

Lloid J.W., 2002: Review of Hydrogeology pertinent to the river Borjomula catchments and Gudjaretis Tskali catchments (KP175-KP192). GIOC.

Zviadadze et al. 2002: Ecological problems connected with Baku-Tbilisi-Jeihan pipeline. Science and Technology #10-12

Beradze R. et al. 1985: Report on 1:25 000 scale geological prospecting K-38-75-b-v-g and K—38-75-G -a-b (in Russian), Georgian Geological department.

Chikhelidze S., 1954: Hydrogeology of Sadgeri spring, Geological report, Georgian Geological department.

Chkhaidze D. et al. 1988: Report on 1:25 000 scale special hydrogeological prospecting works on the Borjomi mineral water resources, Georgian Geological department. (in Russian)

Chkhaidze D. et al.: Report of detail investigation of Borjomi mineral water deposit in 1978-1982, Geological report, Georgian Geological department.

Gabechava J. et al., 2000: Study of water regime of Daba spring (Borjomi district), Geological report, Georgian Glass and Mineral water Co.

Meskhia A. et al., 2002,:Geophysical investigations for groundwater study nearby Daba village in Borjomi region, Georgian Glass and Mineral water Co.

Skhirtladze N. 1958: After Paleogen effusive in Georgia (in Russian)