Hydrogeological characteristics of the „Olympija“ source, Sarajevo

Ferid Skopljak, Mirza Bašagić, Nijaz Škripić

Civil Engineering faculty of Sarajevo - Geology Institute,
University of Sarajevo, Stjepana Tomića st.3, 71 000 Sarajevo, Bosnia and Herzegovina;
E-mail: mbasagic@lol.ba, fskopljak@yahoo.com

Received: November 10, 2006 **Accepted**: December 08, 2006

Abstract: “Olympia” Source (519 asl) is situated in foothill of the olympic mount-aines Igman and Bjelašnica, 15 km westhern from Sarajevo town. Karst aquifer of the joint-cavernous porosity egsist into Middle Triassic limenstones and dolomites. In substratum lies impermeable Lower Triassic layes and in overlayer are impermeable Upper Cretaceous layers, also. By flowing production “Coca-Cola” well at first time in this area, on 171m depth underground potable water is reached under Upper Cretaceous flish.

Key words: Triassic, Upper Cretaceous flish, karst aquifer, groundwater

Introduction

Hydrogeological research works for requirements of company Coca Cola HBC Sarajevo, for the first time in the area of Sarajevo, with well CC Well, researched was underground water of arthesian aquifer in the flysch of the upper Cretaceous. Performed research works have scientific and practical significance and they are resulted in establishment of potable water source “Olimpija” that is bottled in the plant of Coca Cola. In the papers, basic hydrogeological characteristics of this water source are represented.

Location of the Water Source

Water source “Olimpija” is located in Bosnia and Herzegovina, 15 km to the west of Sarajevo, at the locality Mostarsko raskršće,

Geographic location and communication conditions of the water source are favorable. Alongside the water source is a motorway Sarajevo-Mostar, regional road Sarajevo - Kiseljak and railway road Sarajevo - Mostar.

Water source is situated in the valley of the river Zujevina at the altitude of 519 m. a.s.l. River Zujevina, in this part of its watercourse, cuts the watertight rocks of the lower Triassic (T_1) and Upper Cretaceous (K_2). The so-called “Olympic Mountains” Igman and Bjelašnica which peaks are between 1,500 till above 2,000 m a.s.l. are situated on the south side of the source.

Geological characteristics

Geological composition of the wider area is represented by sediments of the Triassic, Upper Cretaceous, Miocene and Quaternary (Figure 2).

Triassic sediments are widely distributed in those terrains. All stages of the Triassic are distinguished in the typical south alpine genesis.

Scientific paper

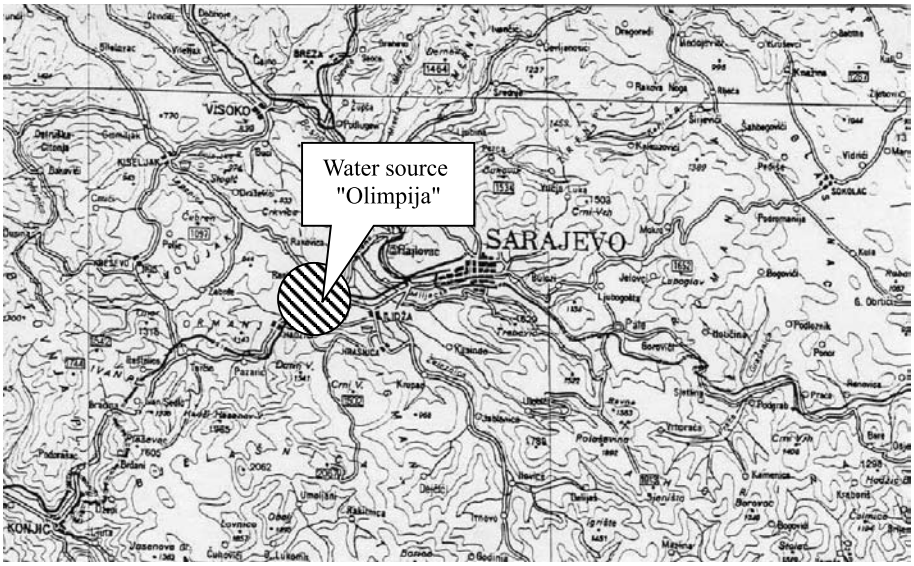

Figure 1. Geographical Location of Water Source "Olimpija", S 1: 500.000

Sediments of the Lower Triassic (T_1) are confirmed in southwest part of the source. They are composed of sandstone, argillites, clayey marls and sandy limestone. They lay over the Permian-Triassic (P, T) marly limestone with lenses of gypsum and anhydrite. Total thickness of the clastite of the Lower Triassic is about 500 m.

The Middle Triassic – Anisian (T_2^1) is developed in the facie of dolomite, dolomitic limestone and limestone. Carbonates of the Anisian outcropping in the southwest of Mostarsko raskršće and they are confirmed by the drilling of "CC Well" in the water source "Olimpija". Those sediments are very cracked and karstificated and lay over the clastite of the Lower Triassic. Their thickness is 200-400 m.

Sediments of the Ladinian (T_2^2) are situated in the smaller areas, in the western part of Mostarsko raskršće. They are represented by volcanic-sedimentary formation, i.e. by sandstone, chert, tuffa, schist, spilite and diabase in the lower and laminar limestone with the nodules of chert at the higher levels. Thickness of the Ladinian deposit is 100-300 m.

The Middle and the Upper Triassic ($T_{2,3}$) are represented with limestone and dolomite. The mountain Igman is, mainly, composed of these sediments. They are intensively tectonised and karstificated. They lay concordantly over the older Ladinian formations and in the higher level they gradually changing in megalodon limestone of the upper Triassic. Thickness of the carbonates of the Middle and Upper Triassic is 300 - 500 m.

The Upper Triassic (T_3) is represented by megalodon limestone, which is discovered at Igman and Bjelašnica mountains, and the thickness is about 700 m.

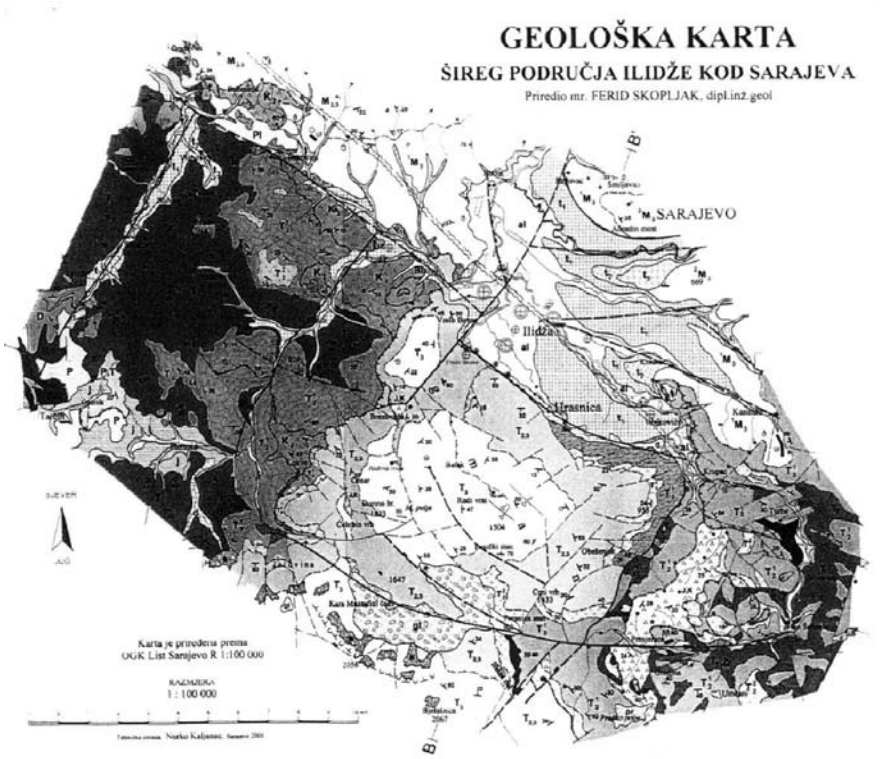

Figure 2. Geological map of Ilidža near Sarajevo area

Sediments of the flysch of the Upper Cretaceous (K_2) has significant distribution in the region of Mostarsko raskršće, Blažuj, Rakovica and Hadžići. They are composed of marl, argillite, calcarenite, marly limestone and breccia limestone. Those sediments are discordant to the Triassic carbonates. The thickness is 140 - 400 m.

Sediments of the Upper Miocene (M_3^1) are situated in the northern part of Mostarsko raskršće. They are represented by marl, argillite, claystone and incoherent sandstones. Total thickness of this series is about 500 m.

Quaternary sediments (Q) are confirmed in the valley of Zujevina river. They are represented by the sediments, such as: debris, gravel and sand. The thickness is 7 - 16 m.

Hydrogeological Characteristics

On the basis of the porosity structure and permeability of the rocks that participate in the composition of the terrain of the wider area of water source “Olimpija”, the following rocks arte selected:

- Practically watertight rocks,
- Mostly watertight complexes,
- Poorly permeable rocks of the fractured porosity,
- Well permeable rock masses of intergranular porosity, and
- Well permeable rocks of cavernous-fractured porosity.

Practically watertight rocks are sediments of the Upper Miocene (M_3^1). Since they are characterized by insignificant and isolated porosity, they are expressively watertight rocks. They have a function of the complete hydrogeological barrier.

Mostly watertight complexes are sediments of the Upper Cretaceous (K_2). Those flysch rocks are mostly watertight and have function of the hydrogeological barrier. At some places, inside of the watertight complex, in the facie of sandstone and breccia limestone, they could accumulate smaller quantity of underground water. In the region of the water source "Olimpija", the sediments of the Upper Cretaceous represent watertight roof of the limestone aquifer.

Poorly permeable rocks of the fractured porosity are the sediments of the Lower Triassic (T_1). Those sediments, together with the sediments of Permian-Triassic (P,T) from the floor, have poor permeability and they mainly represent watertight complex of rocks. However, in the zone of the fault of Zujevina river, they could be more permeable, if they are in the facie of the sandstone and limestone.

Well permeable rock masses of intergranular porosity are subsurface, alluvial sediments. The coefficients of permeability and transmissivity are k = 4.6–7.4 x 10^{-3} m/s and T = 7.3–11.8 x 10^{-2} m^2/s, respectively. In these formations, the deposit of underground water is formed as unconfined aquifer, which is exploited by shallow drilled wells.

Well permeable rocks of cavernous-fractured porosity are carbonate deposits of Anisian (T_2^1), Middle and Upper Triassic ($T_{2,3}$) and Upper Triassic (T_3). There are characterized with expressive fractured – cavernous porosity and good permeability. The transmissivity coefficient of these formations is T = 2.05 x 10^{-3} – 1.52 x 10^{-1} m^2/s. These rocks are the main, deep karst aquifer of this area.

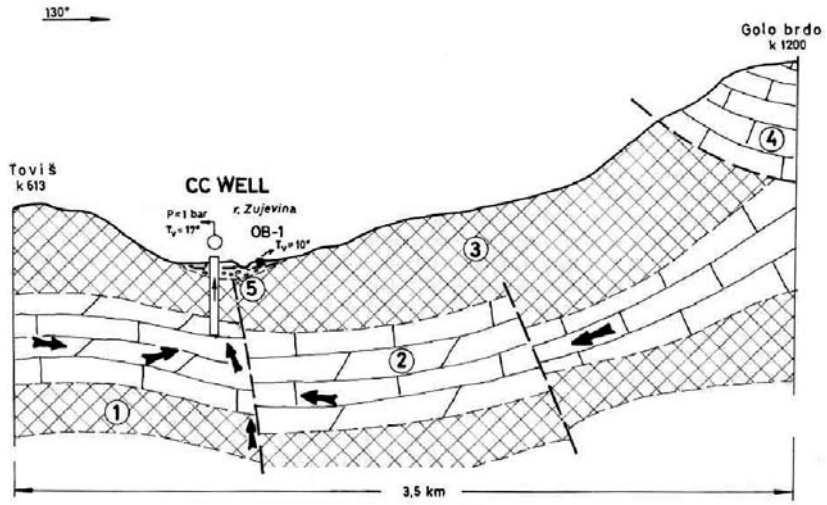

Figure 3. Hydrogeological cross-section of investigation area (Poorly permeable rocks of the fractured porosity – 1; Well permeable rocks of cavernous- fractured porosity – 2 and 4; Mostly watertight complexes – 3; Well permeable rock masses of intergranular porosity – 5)

Type and Site of Source Exploitation

The water exploitation structure is vertically drilled well - 198 m deep. The well is located in the Company Plant, between the building of “souvenir shop” and parking area (Figure 4), and the well is protected with safety fence from trespassing. The water from the well is transported with pipeline to the Plant facilities.

The following hydrogeological profile is determined along the well:

0.00 – 15.00 m
debris, gravel, sand (Q) - subsurface aquifer

15.00 – 171.00 m
argillite, marls, marly limestone and sandstones (K_2) - roof barrier

171.00 – 198.00 m
limestone (T_2^1) - karst aquifer

Well Construction:

- 0.00 – 48.0 m
  pipes ∅ 219.1 / 5 mm with thread - INOX AISI 316 L
- 48.0 – 51.16 m
  reduction ∅ 219.1 / 127 mm - INOX AISI 316 L
- 51.5 – 188.8 m
  pipes ∅ 127 / 5 mm with thread - INOX AISI 316 L
- 188.8 – 190.45 m
  packer INOX AISI 316 L with rubber gaskets
- 190.45 – 198 m
  open hole

Capacity, long term capacity, static and dynamic levels are determined through the test pumping. Pumping test was performed with the submerged pump with three capacities, i.e. three drawdowns, till the quasi-stationary conditions have been reached. The test lasted 168 hours, and the achieved results are given in the Table 1.

Figure 4. The Coca Cola Well (“CC Well”)

Table 1. The test lasted 168 hours, and the achieved results

Pumped quantity (l/s)	Static level (1 bar) (m)	Depression level (m)	Drawdown (m)	Specific Capacity (l/s/m)
$Q_1 = 24$	+10	8.47	$S_1 = 18.47$	$q_1 = 1.29$
$Q_2 = 33.1$	+10	15.50	$S_2 = 25.50$	$q_2 = 1.29$
$Q_3 = 41.3$	+10	22.58	$S_3 = 32.58$	$q_3 = 1.27$

Long-Term capacity of the well is determined on the bases of the calculation and results of the test pumping and it is: $Q_{ex.} = 32$ l/s, with drawdown S = 25.0 m.

Water Quality Characteristics

The water quality analyses are conducted in verified laboratories, and indicate that water is completely in accordance with the regulation of the World Health Organization, European Union and Bosnia and Herzegovina legislation and that the quality of water reflects stability during the hydrological cycle.The physico-chemical analyses indicate that the water from the source "Olimpia" is hydro carbonate-calcium-magnesia type, with mineralization of about 420 mg/l and temperature 16.5 °C. Water does not contain ammonia, nitrate, nitrite, heavy metals, dangerous gases and other inappropriate chemical elements.Microbiological analyses indicate complete absence of bacteria in water.Radiology analyses confirm that the water is useable as potable water. The content of tritium (3H) have the value of 1.2 TU what indicates that underground water did not have any connection with surface or atmosphere water in the last 50 years. Quality of underground water is confirmed by the decision of the authorized Ministry in Bosnia and Herzegovina, according which the underground water can be used for production:

- Bottled potable carbonated and non carbonated water,
- Nonalcoholic and beverage drinks,
- Drinking water enriched with minerals - mineral water,
- In food processing industry, and
- Other industrial requirements.

The Regime of Underground Water

Regime and quality of water of the source "Olimpija" is stabile during the whole hydrological cycle. Those positive characteristics are the result of the geological composition, structural placement and hydrogeological

Table 2. Data of the measured pressure at the top and self-discharge of the well during in the years 2002 and 2003

	2002 - 2003											
	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
PRESSURE (bar)	0.85	0.95	0.85	0.80	1.0	0.9	0.95	0.85	0.80	0.85	1.0	1.0
CAPACITY (l/s) ***(P=0,7 bar)***	-	5.35	5.30	5.25	5.50	5.40	5.50	5.30	5.35	5.40	5.70	5.5

Table 3. Basic parameters of water quality of the well, determined by analyses in different hydrological periods

Hydr. period	pH	Temper	Mineralization	$KMnO_4$	NH_4	NO_2	NO_2	Cl	SO_4	Mn	Fe
		°C	mg/l								
24-12-02	7.3	16.3	430	2.1	0.00	0.70	0.00	5.0	5.8	0.001	0.018
27-03-03	7.4	16.5	420	2.0	0.02	3.7	<0.02	1.3	4.8	<0.002	0.005
02-04-03	7.2	16.3	397	2.4	0.00	0.80	0.00	0.7	1.0	0.00	0.02
08-07-03	7.2	16.5	399	3.12	0.00	3.54	0.00	1.4	1.0	0.00	0.01
03-11-03	7.0	16.5	420	3.55	0.00	0.88	0.00	1.0	1.0	0.00	0.02

characteristics of the source and its wider surrounding area.

Data of the measured pressure at the top and self-discharge of the well during in the years 2002 and 2003 are as follows in Table 2.

Measuring of water temperature along the whole profile of the well during “flow-metering” and video recording of the well, has confirm that the water temperature is constant (T = 16.5 °C).

Chemical composition of the water expresses stability in the different hydrological conditions during one-year period of observation. Mineralization of water is 400 to 430 mg/l. During the period of observation, the water keeps its hydro-carbonate – calcium – magnesia type with insignificant changes of the concentration of certain elements in the chemical composition.

Basic parameters of water quality of the well, determined by analyses in different hydrological periods are as follows in Table 3.

The Reserves of Underground Water

Reserves of the underground water in the source are calculated and verified by the authorized Ministry of Bosnia and Herzegovina (Decision N° 07-18-37/04 dated April 16, 2004).

Confirmed reserves of potable underground water of the source “Olipija” are as follows (according to Bosnia and Herzegovina legislation and classification):

Balanced (P*roved*) Reserves:

- Reserves of Category A
  Q = 5.25 l/s (165,564 m^3/god)
- Reserves of Category B
  Q = 18.75 l/s (591,300 m^3/god)
- Reserves of Category C_1
  Q = 8.00 l/s (252,288 m^3/god)

Potential and Evaluated (P*robable and Possible*) Reserves:

- Reserves of Category C_2
  Q = 9.20 l/s (293,284 m^3/god)
- Reserves of Category D_1
  Q = 15.00 l/s (437,040 m^3/god)
- Reserves of Category D_2
  Q = 12.00 l/s (378,432 m^3/god)

Protection of Aquifer

Limestone aquifer, which scopes underground water “Olimpija”, has very favorable, natural protection aspects. Wider source area, (over 4 km^2), is composed of watertight rocks of Upper Cretaceous flysch. In the floor of those sediments, at the depth of 168 m is the aquifer of underground water, developed in the Middle Triassic carbonates. Since the limestone aquifer is

a confined aquifer, the drilled well has self-discharge of 5.25 l/s and pressure at the top of the well is 0.8-1.0 bars.

Vertical range of rocks, where, in the wider area, there are thick watertight rocks above the aquifer, is extremely favorable from the aspect of the sanitary protection of the water "Olimpija".

Technical characteristics of the well, in which the full steel pipes and INOX casing are installed up to the depth of 168 m and cemented up to the surface of the terrain, prevent any influence of surface water or pollution. Besides to that, the underground water in limestone aquifer is under considerably high pressure, meaning, the possibility of mixing the underground and surface water, objectively does not exist.

Those hydro geological and hydraulic characteristics of the aquifer are ideal conditions for the abstraction and exploitation of underground water because the natural protection conditions are provided.

In the close vicinity of water source "Olimpija" pollution of underground water from the housing, industrial or infrastructure facilities does not exist. All surface and wastewater from this area are taken away and drained by river Zujevina, stream Rakovica and sewage collector Hadžići-Blažuj. As it wass mentioned, the watertight rocks of the Upper Cretaceous, over 150 m thick, developed in the area of approx. 4 km^2, in the way of sanitary protection of the water source, have the first class importance and practically, they designate disposition of the drainage of the surface and waste water.

Zone of the aquifer feeding, is in the mountain area of Igman and Bjelašnica with preserved biodiversity that should be, according to the development projects of Sarajevo Canton, developed into "Geo-park". Besides to that, wider area of Igman is already included into protected zone of the water source Vrelo Bosne what is of the great importance for protection of the water source "Olimpija" at the same time. Mountain terrains in the southwest of the water source are also not inhabited and they are not burdened with urbanization or any other industrial activities. In some places, the weekend houses with periodical way of use are built. Favorable circumstance is constructed sewerage collector Hadžići-Blažuj that takes wastewater and surface influents from the region Binježevo, and the possibility of pollution of underground water even in the case of incident situation do not exist.

Another contribution to the favorable conditions of protection of the water source is the fact that water from the limestone aquifer is microbiologically sterile, without presence of coliform, live and other bacteria, sewage or organic origin. Also, chemical composition of the underground water is completely in accordance with the "Regulation for Potable water", without presence of heavy metal cyanide, greases and oils or other loads that are made by natural or anthropogenic influence. Low level of *tritium* indicates that underground water did not have any contact with surface water or precipitation in the last 50 years.

Conclusion

The aquifer is composed of middle triassic limestone formations, developed at the base of impermeable Upper Cretaceous Flysch deposit substratum 170 meters deep.

The well (CC Well)) was drilled to a depth of 198 m, where a confined aquifer under artesian pressure (0,8 bar) and a flow of 5.25 L was encontered.

Long-Term capacity of the well is determined on the bases of the calculation and results of the test pumping and it is $Q_{ex.}$ = 32 l/s, with drawdown S = 25.0 m.

Groundwater is of excellent quality, as deduced on the basis of physical, chemical and microbiological determinations.

References

Bašagić, M., Skopljak, F. (2003.): An artesian aquifer in Rakovica near Sarajevo area, “Periodical for Mining, Metallurgy and Geology-Materials and geoenvironment”, p. 13-16, Naravoslovnotehniška fakulteta Univerze v Ljubljani in Insitut za rudarstvo, geotehnologijo in okolje, Ljubljana.

Jovanović, R., et al. (1977.): The Basic Geological Map of Former Yugoslavia, Sheet Sarajevo, Geological Survey, Belgrade

Slišković, I., et al. (1983.):The Basic Hydroeological Map of Former Yugoslavia, Sheet Sarajevo, Geology Institute, Sarajevo