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NEW KNOWLEDGE ABOUT THE GEOTHERMAL POTENTIAL OF Sl-1 WELL IN SLAVINOVICI

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SUMMARY

Today's use of geothermal energy is mostly complex and includes several basic branches of utilization, such as: balneology, household use, extraction of various minerals, electricity production, heating of settlements, heating of agricultural farms, as well as industry use.
This paper includes the latest research of thermo-mineral water quality from the Sl-1 well in Slavinovići and according to these results, a new classification and categorization of thermo-mineral water, which on the principle of "air-lift" erupts on the surface of the well.
The results of new chemical analyzes of thermal water from the Sl-1 well in Slavinovići were compared with the data obtained during the construction of the well, which date back to the late 1930s.
Finally, measures for the remediation of the condition of the Sl-1 well are given and also are proposed some further activities that would result withits complex use for balneological, but for any other suitable purpose.

Key words: geothermal energy, thermo-mineral water quality, categorization

INTRODUCTION

In the period between 1929 and 1941, large-scale exploratory drilling for oil was carried out (27 wells were drilled) in the wider area of the city of Tuzla. Most of the wells (24), with depth between 315.0-2025.0 m, were drilled on the Jala-Pozarnica anticline. However, despite many surface appereances of oil, a profitable oil deposit has not been found.

For consolation, a "layer" of warm thermo-mineral water, with temperature of 36 ^{o}C, in the amount of about 500 l/min was drilled in the exploratory well Sl-1, among others (Z. Hadzihrustic, Z.; Ibrisimovic, Z.; Nuhanovic, S.: "Possibility of complex use of thermo-mineral water from borehole Sl-1 in Slavinovici near Tuzla", Monograph of the International Conference on Trends in Modern Mining "TIMC05/06", Proceedings of the RGGF of the University of Tuzla (ISSN 1512- 7044), No. 32, pp. 23-27, Tuzla, 2006).

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For consolation, a "layer" of warm thermo-mineral water, with temperature of 36 ºC, in the amount of about 500 l/min was drilled in the exploratory well Sl-1, among others (Z. Hadzihrustic, Z.; Ibrisimovic, Z.; Nuhanovic, S.: "Possibility of complex use of thermo-mineral water from borehole Sl-1 in Slavinovici near Tuzla", Monograph of the International Conference on Trends in Modern Mining "TIMC05/06", Proceedings of the RGGF of the University of Tuzla (ISSN 1512- 7044), No. 32, pp. 23-27, Tuzla, 2006).

The specificity of this well is the occasional eruptive ejection of hot water with an abundance of gases, without which it could never come to the surface. Its static level is located at 37.0 m (undetermined assumption) below the ground surface.

However, in addition to the mild and pleasant temperature of the bathing water, there are also indications of its medicinal, pharmacological, and even cosmetic value. Also, the need to reduce the share of non-renewable energy sources in the total energy balance of a country leads to an increasing use of geothermal energy. Nine kilometers to the east, on the same anticlinal structure, in the well Pozarnica -1 (1515 m), warm water with a temperature of 50 ºC was also pumped up, which is a sufficient reason for some new research and discoveries of thermal waters in larger quantities.

The pleasant temperature of the thermal water from the well Sl-1 in Slavinovići has been used for many years for the spa activities of the locals, as well as for oral use. The last tests on the well itself were done at the time of its construction, which has already been over 85 years.

All previous research on the well Sl-1 in Slavinovici pointed to the need for more detailed tests of the content and quality of the thermal water, because over time, its chemical composition changed, as well as the yield of the well itself.

The new data, obtained from the conducted research, indicate some irregularities in the old data and also testify to the reflection of the past time, because each eruption period, of any well, is limited by time, but also by the change in the chemical composition of the fluid that is being exploited.

1. THERMAL CHARACTERISTICS OF THE SLAVINOVICI AREA

The most important geothermal parameters, thermal conductivity of rocks, geothermal gradient and heat flow for this area, were mostly obtained based on the results of temperature measurements made during the construction of wells, or by correlation of data obtained from measurements made in wells made in neighboring countries, together with literature data.

The Tuzla Basin belongs to the zone of "medium warm" depressions within the Pannonian depression, which is significantly warmer in its central part. The power of the heat flow in the center of the Hungarian depression is up to 138 mW/m^2, while in the Tuzla basin it is around 60-90 mW/m^2.

It should also emphasized that the determined thickness of the Earth's crust in the territory of Hungary is about 25 km, while the same is much thicker in Bosnia and Herzegovina (the average thickness of the Earth's crust in the territory of Bosnia and Herzegovina is about 45 km).

For the well Sl-1 in Slavinovici, it was determined a strong convective mode of heat transfer, by the circulation of warm waters from greater depths (Miosic, N.: "Geothermal parameters and features of hydrogeothermal regions of Bosnia and Herzegovina", Geoloski glasnik, no. 35, p. 279-307, Sarajevo, 2003).

Data aboutthe well Sl-1 in Slavinovici, which can be obtained by processing literature, mention a geothermal gradient value of 56.3 K/km, which gives a heat flow value of over 120 mW/m^2 (convective parameters), and EU standards each narrow geothermal area with a heat flow value above 100 mW/m^2 is called a thermal field. Some EU countries have lowered this value of the determined heat flow even to a lower level by their laws.

For example, in Hungary, according to their laws, as a positive geothermal anomalie is considered any region, that has a heat flow value above 50 mW/m^2 (Jan-Diederik van Wees, Thijs Boxem, Luca Angelino, Philippe Dumas: "GEOELEC – A perspective study on the geothermal potential in the EU", November, 2013).

So, in the area of Slavinovici, but also in the Tuzla basin in general, geothermal parameters, conditioned by the convective movement of heated fluids from lower chronostratigraphic levels, due to great erosion are quite expressed.

The aforementioned data would have to be practically confirmed by carrying out detailed geological and geophysical tests, especially by carrying out logging measurements in the borehole channel Sl-1 in Slavinovici, which would result in exact data on the values of the heat flow and other thermal parameters in the borehole, but also in the wider area of Jala-Pozarnica anticlines.

During the construction period of the borehole and especially after that, the mentioned tests were not performed, because the borehole was not designed as geothermal, whatever their performance is these days emphasized as an imperative for all future works with purpose of using geothermal energy from this borehole.

In Figure 1, the spatial position of the well Sl-1 in Slavinovici is presented, and in Figure 2 its construction.

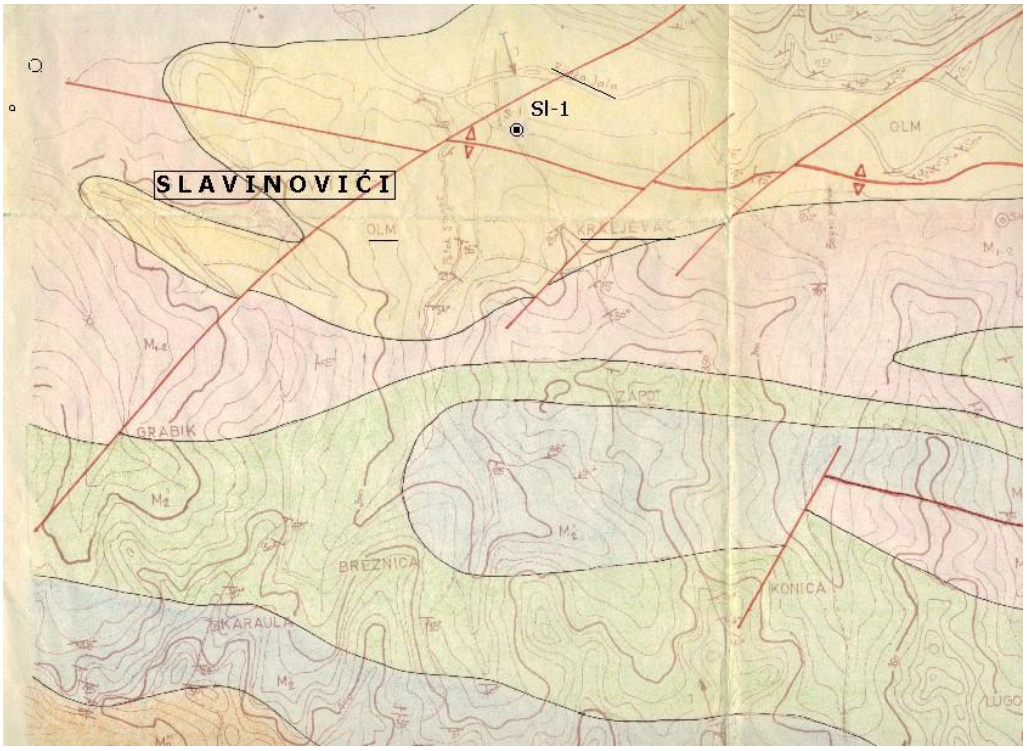

Figure 1. Slavinovici part of Jala-Pozarnica anticline, with the position of the well Sl-1 (Scale - 1: 10 000)

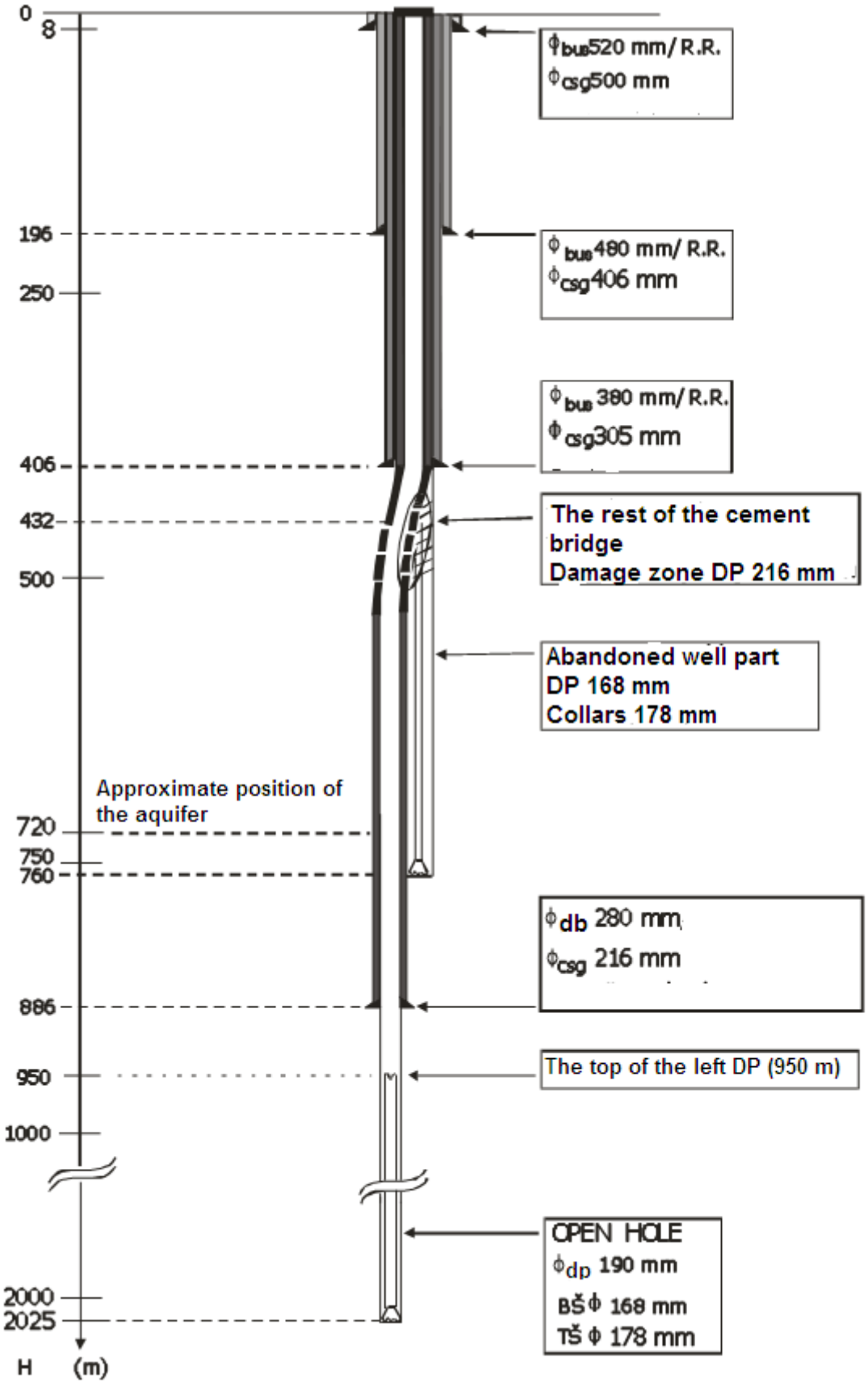

Figure 2. Construction of the exploratory well Sl-1 Slavinovici(Hadzihrustic, Z., 2006.)

2. PHYSICAL AND CHEMICAL ANALYSIS OF THERMO-MENERAL WATER FROM THE WELL SL-1 IN SLAVINOVICI

In March 2021, a new sampling and analysis of water from the well Sl-1 were carried out. The sample was taken from the surface of the terrain, i.e. at the point of thermo-mineral water outflow. Water samples were analyzed in two laboratories at the sametime; one sample was tested in the laboratory of ZZJZ TK (Institute of Public Healt of Tuzla Canton), and the other one in the laboratory for chemical analysis of water at RGGF Tuzla (Faculty of Mining, Geology and Civil Engineering Tuzla).

The results of physical and chemical tests are given in tables 1 and 2.

Table 1. Results of the physical-chemical analysis of thermo-mineral water from well Sl-1 in Slavinovići, obtained by the analysis carried out in the laboratory of ZZJZ TK (Institute of Public Health TK)

PARAMETER	*UNIT*	*VALUE*	*TEST METHOD*
Color	-	Yellowish	Sensor
Smell	-	likeH_2S	Sensor
Taste	-	-	Sensor
Turbidity	NTU	4,9	BAS EN ISO 7027-1:2017*
pH (25℃)	pH	8,27	BAS EN ISO 10523:2013*
Consumption KM_nO_4 (oxidizability)	mg/ l O_2	5,12	Volumetry
Dry residue	mg/l	10434	Gravimetry
Electrical conductivity (25℃)	$\mu S/cm$	11200	BAS EN ISO 27888:2002*
Electrical conductivity (20℃)	$\mu S/cm$	10036	BAS EN ISO 27888:2002*
Ammonium (NH_4^+)	mg/ l	2,75	Spectrophotometry
Residual chlorine	mg/ l	0,00	Colorimetry
Chlorides	mg/ l	2100,00	Volumetry
Nitrites (NO_2^-)	mg/ l	0,01	BAS EN 26777 :2000
Nitrates (NO_3^-)	mg/ l	5,47	Standard Methods for the Examination of Water and Wastewater, 4500 NO3-B 2017*
Ferrum (Fe)	mg/ l	0,21	Spectrophotometry
Manganese (Mn)	mg/ l	0,037	Spectrophotometry
Total hardness	$°nj$	1,23	Volumetry
Alkalinity	$°nj$	151,20	Volumetry
Sulfates	mg/ l	1,78	Spectrophotometry
Calcium (Ca)	mg/ l	3,20	Volumetry
Magnesium (Mg)	mg/ l	3,40	Volumetry
Bicarbonates	mg/ l	3294,00	Volumetry

Table 2. Results of the physical-chemical analysis of thermo-mineral water from well Sl-1 in Slavinovići, obtained by the analysis carried out in the laboratory of Faculty of Mining, Geology and Civil Engineering Tuzla

PARAMETER	***DETERMINED CONCENTRATION (mg/l)***
Sodium (Na^+)	2553,00
Calcium (Ca^{++})	2,213
Magnesium (Mg^{++})	1,300
Potassium (K^+)	16,630

Analyzing the data obtained from the latest research (year 2021.) and comparing it with the data dating from the construction of the well Sl-1 in Slavinovici (year 1936), qualitative conclusions can be drawn about the type and quality of thermomineral water, after 85 years of work, i.e. periodic eruption of well Sl-1 in Slavinovici.

A comparative analysis of the chemical composition of thermomineral water is presented in table 3 (the results shown in the table, which date from the period of construction of the well, were taken from a depth of 540 m).

Table 3. Comparative analysis of the basic parameters of the chemical composition of thermo-mineral water from well Sl-1 in Slavinovici, according to the results, by years of water testing

Parameter	***The results of the analysis in 1936. (mg/l)***	***The results of the analysis in 2021. laboratory ZZJZ TK (mg/l)***	***The results of the analysis in 2021. laboratoryRGGF Tuzla (mg/l)***
Na^+	2026,30	-	2553,00
K^+	5,00	-	16,63
Ca^{++}	13,00	3,20	2,21
Mg^{++}	3,70	3,40	1,30
Cl^-	1434,00	2100,00	-
SO_4^{--}	13,40	1,78	-
HCO_3^-	2942,60	3294,00	-

Cation-anion ratios from the Suharev classification, in order to determine the categorization of water from the well Sl-1, this time gave the following coefficients:

$$\frac{Na^+ + K^+}{Cl^-} = \frac{2553+16,63}{2100} = 1,22 > 1 \Rightarrow \textit{bicarbonate-sodium or sulfate-sodium type of water}$$

$$\frac{\gamma Na^+ - \gamma Cl^-}{\gamma SO_4^{--}} = \frac{2553-2100}{1,78} = 142,9 > 1 \Rightarrow \textit{bicarbonate-sodium type of water}$$

$$\frac{SO_4^{--}}{Cl^-} = \frac{1,78}{2100} = 0,00085 < 1 \Rightarrow \textit{chloride group of water}$$

So, it can be seen from the presented that, although the coefficients have changed to a greater or lesser extent, it does not affect the final result, i.e. the water still belongs to the same type, group and subgroup of thermomineral waters.

Based on the latest data, it can be concluded that the thermal mineral water from well Sl-1 still belongs to the **genetic type of hydrocarbonate-sodium waters** and that within this type of water it can be classified in group C, i.e. in **chloride waters** with the corresponding **subgroup of sodium waters**.

3. CAPACITY OF THE SL-1 SLAVINOVICI WELL

According to the analyzed literature data, which were available to us, the determined capacity of thermomineral water, measured at the time of the construction of the well Sl-1 in Slavinovici (year 1936), was about 500 l/min (Z. Hadzihrustic, Z.; Ibrisimović, Z .; Nuhanovic, S.: "Possibility of complex use of thermo-mineral water from borehole Sl-1 in Slavinovici near Tuzla", Monograph of the International Conference on Trends in Contemporary Mining "TIMC05/06", Proceedings of the RGGF of the University of Tuzla (ISSN 1512-7044), No. 32, pp. 23-27, Tuzla, 2006). This information has not been checked for years.

The measurements, carried out in September 2020, determined the total capacity of well Sl-1 to be about 300 l/min (about 5 l/s).

Capacity measurements were carried out using the "primitive" method, that is, using a container with a volume of 5.0 liters and a stopwatch, whereby the time required to fill the full volume of the container was measured on each of the showers, that is, the distribution lines (figure 3). The total capacity was obtained as the sum of the individual capacities of the outlet lines (showers) at the wellhead.

Figure 3. View of the mouth of the borehole Sl-1 in Slavinovici, with the construction of the choke manifold (showers) (Photo: Nuhanovic, S; Barusic, B., 2020.)

It should be noted that the capacity measurement was carried out during the dry period, and that the measurement was carried out in a period that corresponds to the half of the beginning of the eruptive period of the well.

If we compare the stated capacity values of 500 l/min (measured 85 years ago) and 300 l/min (measured in September 2020), we can conclude that the drop in pressure, i.e. the capacity of the well, is realistic and quite expected, since the thermo-mineral water, in such a long period of time, was not "returned", i.e. injected back into the reservoir, but was wasted, i.e. spilled into the surrounding watercourses, which not only wasted energy, but also polluted the environment.

4. TEMPERATURE OF THERMO-MINERAL WATERAT THE WELL MOUTH SL-1 IN SLAVINOVICI

The data about the temperature of the thermo-mineral water at the mouth of the borehole Sl-1 in Slavinovici do not match the literature. Namely, in the paper "Geothermal parameters and features of hydrogeothermal regions of Bosnia and Herzegovina" (Miosic, N., Geološki glasnik 35, UDK 551.1/4 (058) "55", page 279-307, Sarajevo, 2003) the temperature at the mouth of the borehole Sl-1 in Slavinovici was stated to be 34.5 ^{o}C.

In the paper "Possibility of complex use of thermo-mineral water from well Sl-1 in Slavinovici near Tuzla" (Z. Hadzihrustic, Z.; Ibrisimovic, Z.; Nuhanovic, S., Monograph of the International Conference on Trends in Contemporary Mining "TIMC05/06", Proceedings of the RGGF of the University of Tuzla (ISSN 1512-7044), No. 32, pp. 23-27, Tuzla, 2006) states that the temperature at the mouth of well Sl-1 in Slavinovici is 36^{o}C.

Temperature measurements of thermomineral water at the mouth of the borehole Sl-1 in Slavinovici were carried out in June 2021 and was determined to be 34 ^{o}C.

5. THE MODE OF OPERATION OF THE WELL SL-1 IN SLAVINOVICI

The mode of operation of the Sl-1 geothermal well in Slavinovici was established in the period August-September 2020, taking into account the periodic, eruptive operation of the well, based on the gas-lift principle.

Earlier data indicated that the geothermal well in Slavinovici has a period of "active work" of 12 hours, and a some kind of a "rest"period that lasts 36 hours (Z. Hadzihrustic, Z.; Ibrisimović, Z.; Nuhanovic, S.: "Possibility of complex use of thermomineral water from borehole Sl-1 in Slavinovici near Tuzla", Monograph of the International Conference on Trends in Modern Mining "TIMC05/06", Proceedings of the RGGF of the University of Tuzla (ISSN 1512-7044), no. 32, pp. 23-27, Tuzla, 2006).

Observations made in the unknown period established the following:

- 25.08.2020. – the well stopped working at 17:00 h
- 27.08.2020. - the well started working at 04:00 h
- 27.08.2020. – the well stopped working in 20:00 h

The period of "rest" of the well was determined to be 35 hours, while the period of "work" of the well was 16 hours. To some extent, this coincides with the defined operating regime of the Sl-1 well in Slavinovici, which implies 12 hours of "work" and 36 hours of "rest" of the well.

Due to the short time of monitoring the regime of the borehole, it can be concluded that the borehole Sl-1 in Slavinovici still operates according to the same regime, even after 85 years of eruption, depending on the amount of precipitation in a certain period of time. Also, the obvious conclusion is that the thermomineral outcrop is fed from the surface of the terrain, by weathering and surface watercourses, which is logical, taking into account the mentioned fissures and erosion of the geological formations that make up this terrain.

Also, it should be noted, since it is quite important observation, that the gas which brings the water to the surface is flammable (burns on the pipe) in atmospheric conditions.

DISCUSSION AND CONCLUSIONS

Back in 1937, the drilling of the exploration well Sl-1 in Slavinovići, near the city of Tuzla, was completed. This deep exploration well, with depth of 2025 m, is located approximately at the top western part of the 9 km long Jala-Pozarnica anticline.

The well did not produce the expected oil and gas results, but during drilling, around the depth of 720 m, it suddenly appeared hot mineral water, with temperature of 36 ^{o}C, in the amount of 500 l/min. The water erupted in the form of a 25 m high water column, with an abundance of oil gases, which constitute the driving energy of the eruption.

The duration of one eruption cycle is approximately two days (48 hours), i.e. 12 hours of eruption and about 36 hours of rest, which was also confirmed by these studies. Thermomineral water from well Sl-1 in Slavinovici, according to the assumptions, breaks through the damaged part of a casing ϕ 216.00 mm, in the part of the well with a strong "dog leg", which is why the original construction of the well was abandoned. .

The mentioned claim must be proven by more detailed geological, and especially geophysical research, in order to define the mentioned phenomenon in its entirety.

According to the research results, thermo-mineral water from the well Sl-1 belongs to the group of low enthalpy waters, and can be used for many purposes, and even, with possible additional heating, for heating and cooling the space.

The research carried out in this paper shows the following:

- If we adopt the determined capacity of the well of 300 l/min, its energy potential, according to our calculations, corresponds to the equivalent of 2200 kg/day of lignite from the "Kreka" coal mine. Expressed in money, it is about 200 BAM/day.
- The separation and "capturing" of oil gases at the wellhead, and their adequate use, could significantly increase its energy potential.

However, although the water from the well Sl-1 does not have enough energy potential for its energy utilization, there are all indications that it has a much greater value if it is used for recreational purposes, and in medicine and pharmacy. In several developed countries, geothermal energy has been used for these purposes for many years.

Cation and anion analyzes of microelements promote this water as bicarbonate-sodium water, which we proved by calculating the corresponding coefficients.

Thermomineral water from well Sl-1 in Slavinovici should have a high balneological value and be used as drinking (bottled) water.

For other purposes, it would have to be used not far from the mouth of the well, because it cannot withstand longer transport, due to the relatively low temperature (34 ^{o}C). However, as bottled water, this water can also be used over much longer distances.

Based on all the above considerations, it is suggested that, in order to further use this water, conduct general and targeted research in the direction of its potential multiple uses.

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