

## Research of Available Mineral Geothermal Water Resources for Utilization in Latvian Sanatoriums

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### ABSTRACT

In the Latvian resort city Jurmala there are currently three sanatoriums left that admit guests with different kinds of diseases. A few years ago there were many other sanatoriums, but because of the quite difficult economical situation most of them were closed. Now the situation is changing and it is necessary to find out whether geothermal mineral water resources are good enough to attract foreign investors. One of the biggest sanatoriums that were closed is the sanatorium "Baltija". Unfortunately, no new wells have been drilled in years, so we had to base our research according to older, existing data.

Research has been done in order to understand the hydrogeological characteristics of mineral water resources, using the data of the wells "Baltija-1" and "Baltija-2", which are located close to the former sanatorium "Baltija". The research work involved characterizing geological structure and hydrogeological conditions of the region, analysis of operation regime of the well, actual yield of the well is estimated, and chemical and balneological characteristics of mineral geothermal water are analyzed.

### 1. INTRODUCTION

First of all it was necessary to choose a research area. In the majority of cases mineral waters used for medical purposes possess minerals in the amount of 5,1 – 7,2 g/l as well as chloride calcium-sodium contents.

This is available in the operating well "Baltija-2", the mineral waters of horizon of Pernava and the ones of the upper part of horizon of Kemerī correspond to such requirements entirely. All the other aquifers and complexes contain fresh and low-salt waters (located strategically higher than horizon of Pernava) and brines (located strategically lower) and neither for utilisation nor in salinity content do these correspond to the necessary requirements.

### 2. GENERAL INFORMATION

#### 2.1. Geographical and Administrative Status

The area of research covers the territory appropriate for reconstruction and construction of both old and new sanatoriums – seaside of the Gulf of Riga from "Kemerī" resort situated in the west to the estuary of Lielupe River in the east 10-12 km far from the seaside into the mainland, i.e. it covers the territory about 300 km<sup>2</sup> (Figure 1).

The site of research is located at the seaside of the Gulf of Riga and Dzintari village and it covers the territory of the researched well "Baltija-2" and utilised well "Baltija-1" that are located 15 m from each other. Jurmala, a resort town, fully includes the research area.

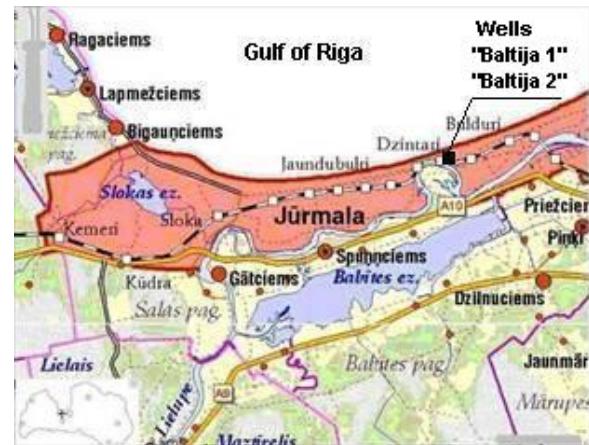


Figure 1: Research area.

"Baltija" sanatorium, which is closed at the present time, is located at the seaside of the Gulf of Riga 17 km north-west of downtown Riga, but "Baltija-2" well is located 200 m west of the main building of the sanatorium, in the dune zone.

The Riga-Jurmala premium class highway as well as the electrified railway Riga-Tukums crosses the whole Jurmala town along the seaside. The Gulf of Riga, 15-20 m deep in the central part and 1-3 m deep in the coast side, is the largest hydrographical unit of the present site.

#### 2.2. First Data about Mineral Waters

The first data about mineral waters of Pernava and the Lower Devonian aquifer complex and the region of research was received in 1948 just after drilling of the "Kemerī" well, which revealed almost the whole aquifer complex. The data from this well has been poorly preserved so nowadays only a few hand-written materials are available. According to the results of this well's open-cast drilling of the Middle and Lower Devon, the first in Latvia, has distinguished the horizon of Pernava and area of Kemerī. The analysis of the horizon of Pernava waters revealed that they possess chloride calcium-sodium contents, their mineralization runs up to 5,5 g/l and the contents of bromine is 12 mg/l. These waters have been used then by the clinic of the Kemerī resort as mineral medical and medical low-mineral waters. In 1973 the "Kemerī" well went out of operation. Instead, a new operating well, 450 m deep, was drilled ("Kemerī-1").

The first data on deep geological structure in hydrogeological conditions of the region was received in 1971, when the "Kemerī-2" deep well had been drilled and researched. This well revealed the whole aqueous base and layers of crystalline base.

The lower and the upper parts of the Cambrian aquifer complex were subject to hydrogeological research. As a result the same type of both parts has been determined. Each part represented chloride sodium brines with mineral content equal to 116-118 g/l as well as high contents of bromine (280 mg/l).

From 1959 various sanatoriums and pensions of Jurmala have been paying great attention to the mineral medical waters of Pernava and the Lower Devonian complex. Due to this fact, at the territory of seven sanatoriums and one old people's home operating wells have been drilled to the horizon of Pernava of the Middle Devon.

Because of wrong project depth several wells revealed sediments of the Lower Devon, that caused an increase of mineralization of selected waters from 4,9 g/l to 7,0 g/l. The majority of wells were drilled without selection of kernel so the determination of horizons according to lithologic features was executed on the basis of logging. Before initial operation of wells, short outputs of water were carried out and the samples were taken for chemical analysis.

The following Table 1 contains the volumes of consumed mineral water of horizon of Pernava in sanatoriums and old people's homes in Jurmala.

**Table 1: Volume of consumed water by sanatoriums**

Name of the well	Year of drilling	Volume of consumed water, m <sup>3</sup> /24 h
Kemeri-I	1973	100,0
Baltija-I	1959	129,0

**Table 2: Registered data of the wells**

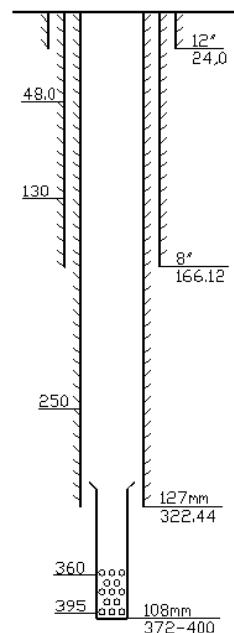
Well	Year of drilling	Abs. mark of estuary	Absolute mark of hydrostatical level	Mineralisation	Mineral water consumption, m <sup>3</sup> /day (1977.g)
Kemeri-1	1973	+6.0	+34.1	5.2	100
Baltija-1	1959	+5.0	+38.0	5.65	108.8

**Table 3: Testing results**

Well	Testing results			
	Decrease, m	Dynamic level, m	Yield, m <sup>3</sup> /day	Specific yield, m <sup>3</sup> /day
Kemeri-1	8.0	+26.1	865	108
	13.0	+21.1	1430	110
	27.5	+6.6	2680	98
Baltija-1	10.0	+28.0	1040	104
	23.0	+15.0	1460	63.5
	37.0	+1.0	1580	59.0

### 3. ANALYSIS OF OPERATION REGIMES OF THE WELL "BALTIJA-1" AND COMPARISON WITH THE OTHER WELLS

The casing schedule of the well "Baltija 1" is shown in Figure 2. The other wells have similar construction.



**Figure2: Construction of the well.**

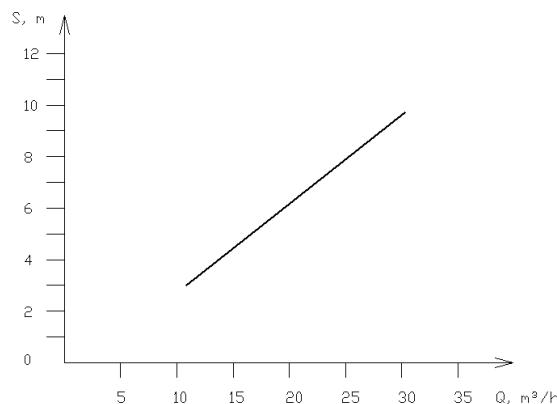
For comparison total water consumption from wells "Baltija 1" and "Kemeri 1" has been registered and summarised in Table 2. Some test results are shown in Table 3.

Following is the performance of the well "Baltija 1" - 10 hours per day, total water consumption in 1975 was 18250 m<sup>3</sup> (average 68,6 m<sup>3</sup>/day); in 1976 – 30692 m<sup>3</sup> (average 116,3 m<sup>3</sup>/day); in 1977 – 292 12m<sup>3</sup> (average 110,7 m<sup>3</sup>) and in 1978 (until August inclusive) – 185 24 m<sup>3</sup> (average 108,8 m<sup>3</sup>).

According to registered data, the water daily (24 hour) consumption from the well from 1975 to 1978 has almost doubled. This is due the increased of utilization of mineral waters for medical purposes in the "Baltija" sanatorium. In the same period of time the dynamic level during the exploitation of mineral waters has decreased, proportionally to the water consumption.

Annual measurements of piezometric level, starting from 1975, illustrated that it stayed constant. Calculations that have been made to find level lowering over the last 19 years, taking into account that daily mineral water consumption was 110 m<sup>3</sup>/day, shows that lowering could be merely 1.6m, but such water consumption wasn't all 19 years, but just the last 3 years – level lowering should therefore be even less. This fact leads to the conclusion that piezometric level measurement at the beginning wasn't made correctly.

Observations during the previous 4 years illustrated the stable status of the level lowering taking into account the water consumption 68,6-116,3 m<sup>3</sup>/day (Figure 3).



**Figure 3: Dependency diagram of water consumption from lowering during 1975-1978 regarding "Baltija-1" and "Baltija-2" wells.**

From the time the "Baltija-I" well started operating and until 1978 the mineralization of water and the contents of its basic components both have almost been constant. The temperature of mineral water at the well head from 1975 till 1978 was constant (about 15°C). In the research area similar hydrogeological studies were carried out in the operating "Jaunkemeri" well.

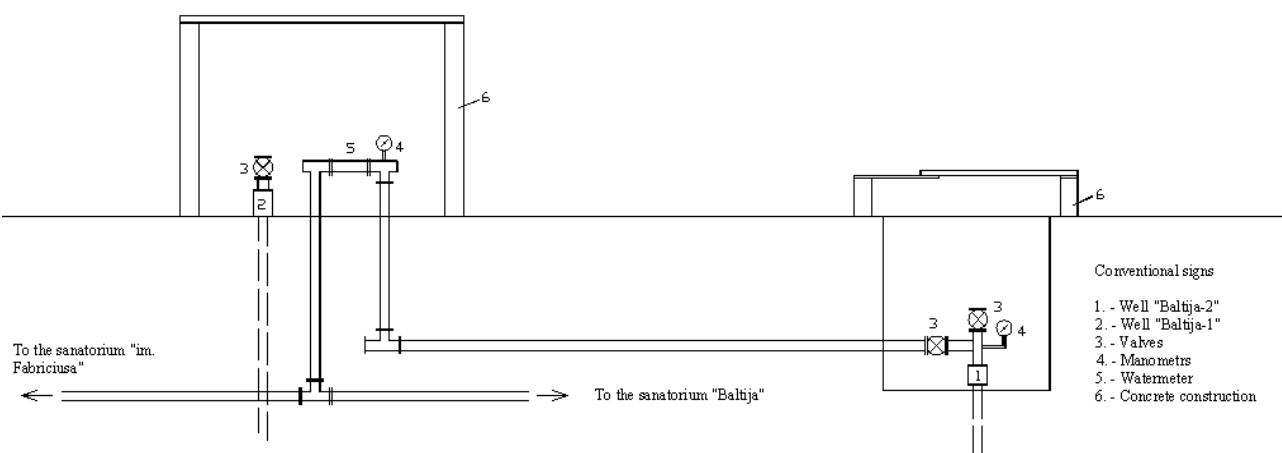
According to the research results of the wells "Baltija-2" and "Jaunkemeri" wells (Table 4) the conclusion may be made that they do not contradict each other and they are equal considering many features.

The basic disadvantage of all the operating wells is discrepancy of the amount of the water consumption and the possible well yield.

Being equipped by the too heavy upsetting pipes of a large diameter, each of wells may provide, according to their application, the need in mineral water of all the sanatoriums in the central part of Jurmala. A schematic diagram of the connection of well "Baltija-2" to the mineral water supply system is shown in Figure 4.

**Table 4: Research results of the wells "Baltija-2" and "Jaunkemeri"**

Parameters	"Baltija-2"	"Jaunkemeri"
Thickness of revealed horizon (complex), m	42.0	51.0
Piezoconductivity, m <sup>2</sup> /24 h	$4.24 \times 10^6$	$2.2 \times 10^6$
Hydroconductivity, m <sup>2</sup> /24 h	130.6	130.0
Maximum output, m <sup>3</sup> /24 h	1380.0	2090.0
Dynamic level that corresponds to it, m of absolute altitude	+18.8	+5.0
Specific output, m <sup>3</sup> /24 h	71.8	76.8
Water mineralization, g/l	6.0	5.5
Temperature of water at the well head, °C	15.0	15.2



**Figure 4: Schema of connection of well "Baltija-2" to the mineral water supply system.**

#### 4. SUGGESTED IMPROVEMENTS

- Modernize the structure of the wells, taking into account the possible need in mineral water.
- According to the final application of mineral waters and their necessary mineralization in order to preserve ground waters from exhaustion only one aquifer horizon (of Pernava or Kemerī) should be considered further.
- Organize effective control of all the wells that bring out mineral waters of Pernava and the Lower Devonian complex, execute systematically and register in them variations of consumption, pressure, temperature and chemical contents.
- It is necessary to recommend more efficient strategy of supply system of mineral water to sanatoriums. Technical and economic estimations illustrate that the cost of water-pipe construction of polyethylene pipes with diameter 110 mm to the distance 1.3 km long is cheaper than the cost of the drilling of one operating well.

#### 5. CHARACTERISTIC OF THE QUALITY OF GROUND WATER

The ground water of the estimated field is characterized by a quite wide variety. Aquifer horizons and complexes which are deposited higher than Pernava and the Lower Devonian aquifer complex contain fresh, low-salt and salt water.

Fresh, low-salty and salty waters are related to quaternary deposits and the ones of Daugava, Dubniki, Plavinas, Shventoysk and Starooscalsk.

The Cambrian aquifer complex which is located lower than Pernava and the Lower Devonian aquifer complex contains the brines.

In the process of testing mineralization of water in well "Baltija-2" varies from 5,9 to 6,25 g/l. Among anions a chlorine dominates which takes 80,07 – 83,2 equivalent %, but among cations a sodium does (Na + K) – 47,2 – 51,3 equivalent %. The concentration of calcium does not exceed 33,9 equivalent. Among microcomponents the following ingredients have been found in waters: bromine (12,8-18,6 mg/l), boric acid (3,9-5,0 mg/l), strontium (3,2-3,7 mg/l) and in smaller amounts iron, aluminium, lithium, zinc, nickel, lead and others.

The water has low saturation of gases and the latter does not exceed 20 sm<sup>3</sup>/l. The contents of gas is nitric (amounts to 97-96,3 volume %). In small amounts the following components are present: carbonic acid – 0,00-1,3 %, methane – 0,00-0,5% and hydrogen – 0,046-0,071%. Chemical composition of mineral water in the well "Baltija-2" is shown in Table 5.

Such waters are classified as chlorine-calcium-sodium mineral waters with medium mineralisation (5-6 g/l) and with relatively high Bromine content (13-17 mg/l), neutral (PH 6.8-7.2), cold (T 13-16°C), with the main content of gas - nitrogen.

Experience of utilisation of chlorine-calcium-sodium mineral waters from well "Baltija-1" has shown that they are an aggressive environment for iron. The 19 years of utilisation have shown that the pipeline is subject to

corrosion. That is why it is recommended to use plastic pipelines.

From utilisation of the mineral waters in a swimming pool, some iron oxide can be found on the walls of the swimming pool.

**Table 5: Chemical composition of mineral water in the well "Baltija -2"**

Components	Saturation	
	from (mg/l)	until (mg/l)
pH	6.8	7.2
Sodium	1006	1294
Calcium	657	691
Magnum	210	235
Potassium	37	40
Strontium	3.2	3.7
Oxidized iron	0.2	0.87
Chlorine	2900	3235
Sulphate	805	844
Hydrocarbonate	73	98
Bromine	12.8	18.6
Fluorine	0.4	0.9
Boric acid	3.4	7.0
Silicic acid	7.3	10.3
Mineralization	5950	6250

#### 6. SUMMARY OF RESEARCH

- During utilisation of waters of Pernava and the Lower Devonian aquifer complex, gradual lowering of level will take place. According to the calculation it is going to be about 6.8m. Calculation results show that during the whole exploitation period, well "Baltija-2" will remain artesian (self flowing).
- The well head pressure is 3,3 atmospheres: piezometric level of water is set at the absolute point +38,0 m.
- The maximum efficiency of "Baltija-2" operating well is 1380 m<sup>3</sup>/day at the lowering 21,18 m that, to a certain extent, characterizes the efficiency of the horizon.
- Estimated hydrogeological parameters: "km" – 130,6 m<sup>2</sup>/day and "a" – 4,24 x 10 6 m<sup>2</sup>/day.
- According to the results of discharge testing, with the output 3 l/s during 185 days and the discharge in exploitation mode during 30 days with the output 6 l/s no changes have been established in

mineralization of water and the contents of basic components in it.

- According to the results of chemical analysis the waters of Pernava and the Lower Devonian complex have been referred to as chloride calcium-sodium middle-mineralization medical low-mineral waters without specific components, the cold ones. This complex can be used for treatment of chronic gastritis with the secret deficiency and chronic colitis.

## 7. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER EXPLOITATION OF THE WELLS

According to specific terms of the field of estimated mineral waters the following actions can be recommended for it's the most efficient exploitation and the control:

- For accident-free operation of a well it is necessary periodically, at least one time annually, to execute the control output of water on it in the mode of the maximum efficiency in order to avoid sanding.
- The mode observations of consumption, dynamic level, temperature and the quality of water should be carried out according to the special schedule.

Operating wells "Baltija-1" and "Baltija-2" are equipped by their own common zone of strict sanitary preservation, above the well heads capping brick structures with locked entrances are erected, the well head equipment and piping are made of polyethylene material and equipped by registration devices.

During the execution of hydrogeological researches of Pernava and the Lower Devonian exploitation horizon the following results have been received:

- Horizon roofing which contains chloride calcium-sodium mineral waters at the territory of "Baltija" sanatorium is deposited at the depth of 360 m or - 355 m of the absolute altitude.
- The revealed horizon power is 42 m, 33 m of them is the efficient power.
- The horizon consists of white quartz arkoses with siltstone and loam layers. Sandstones are water consuming layers.
- From above-deposited horizons which contain fresh waters it is separated by the thickness of almost impenetrable loam-carbonated layers of Narovsk horizon with capacity 110 m. From

below-deposited Cambrian aquifer complex which contains brines it is detached by the great thickness (to 550m) of practically impenetrable layers of Wenlock and Ordovician.

- The revealed part of the horizon contains forcing calcium-magnesium mineral waters with mineralization up to 6,25 g/l and the contents of bromine amounts to 19,0 mg/l. The temperature of water at the well head is 13-16°C, formation water - 16°C.

The mineral water can be used in swimming pools if deironized, because otherwise iron deposits colour the bottom and walls into reddish colour so the water seems muddy.

Besides chloride-sodium water also contains bromine brines (120-130 g/l) that can be used successfully for moderate mineralization in Jurmala for medical purposes. This type of water is valuable and it has made famous such resorts as Ust-Kachka, Morshin.

Bromine brine is worth using for treatment of illnesses such as internal digestion, metabolism, cardiovascular system, support and movement parts, gynaecological and nervous system diseases. In the future this type of water may be applied in the resorts of Jurmala, Kemer, Baldone, Cirulishi.

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