Balneological properties of the geothermal water in Latvia

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Abstract.
The future of geothermal energy utilisation in Latvia could be most successful if the old sedimentary water could be used for balneological purposes. The temperature of the geothermal water in tourist regions mostly is not exceeding 40^{o}C. Notwithstanding balneological indicators of the water are on a high level, comparing with thermal waters in the famous resorts of the world. This report addresses, in outline, the potential for balneological purposes of geothermal water in Latvia in the recreation and health industry.

Keywords.
Balneology, geothermal, swimming pool, Latvia.

Introduction.
Recent changes in the Latvian social and public health policy promote the use of geothermal hot water in balneological applications. Any study into the use of geothermal water for an outdoor swimming pool or Health Spa development in Latvia, entails not only investigating the use of the earth's heat in the form of thermal water with the temperature 25 - 50°C, but also the use of its balneological and therapeutic properties for Health Spas and recreational activities for foreign and local tourists [7]. Multifarious integrated use of the resource is generally more cost-effective and profitable, than singular direct use of the geothermal resource for example in heating etc.

At present there does not exist an internationally accepted definition of mineral waters, which will hold in law. Certain common points are, however, found in all commonly used definitions. The main principle is that mineral water is always considered as being "natural water obtained from natural springs or artificially opened wells". For water to be classified mineral water, it must contain a minimums of 1,000 mg/kg total dissolved solids (TDS) or more than 250 mg/kg of carbon dioxide. This value has been specified for medical re-convalescence, and health spring water centres by "Deuchen Baaderverband"(Germany). Other countries in Europe accept this value. Under this specification, geothermal water in the wells in Riga/Jurmala region of Latvia quality as mineral water, the values for their water being 100 times more than required. TDS content in this water is 3 times higher than that in the famous "Blue Lagoon" in Iceland and chemical composition shows that this water could have very favourable impact on the skin.

Geothermal prophylactics and therapy.
The use of geothermal waters for bathing, therapeutic purposes and recreation represents man's oldest known use of geothermal resources. The culture of balneology goes back to ancient times. This culture has been particularly prestigious in Europe and Japan. In Europe

there are currently in operation several hundred spas, which are visited by tens of millions of guests every year [5].

The temperature of the spring water does therefore not constitute a basic criteria for the definition of mineral waters, like in the thermal resorts “Montecatini” (Italy) source Tettuccio temperature is just 24,6 °C or “Vittel” (France) Grande Source, where temperature is 11°C.The thermal effect of medical waters as far as the effects of therapy are concerned may be summarised as follows [2]. Vasodilatation increases in the veins of the skin thereby accelerating the metabolic processes in the cells of the skin. In addition to the physical activity, the mechanical force caused by the motion of water molecules provides a micro-massage. In this way capillary dilatation and blood circulation improve, oxygen supply is increased and the metabolic processes are intensified in the skin and subcutaneous cells. In addition to geothermal effects, it has been discovered that waters high in mineral salt content have diverse beneficial chemical effects on diseases through the absorption of a certain quantity of the dissolved mineral materials is via the skin.
A good example of this is the utilisation of sulphurous waters (Harkany in Hungary) where according to isotope tests the sulphide water penetrates the skin 8 to 10 times faster then sulphate. As a result, the skin veins first contract and then dilate. An additional benefit is a non-toxic inflammation reduction, desensitising and parasite killing effect. A significant part of the absorbed sulphur is stored in the skin and can be detected in the skin and in hair for weeks after bathing. A similarly outstanding medical significance is attached to the free carbonic acid coming from the ground with the geothermal water, which during a carbonic acid bath treatment, intensively improves blood circulation and is therefore of significant medical importance for circulatory and heart disorders. This method is for example used in the well-known Heart Clinic of Balatonfüred (Hungary).
Health benefits due thermal effects of the balneological water can also be quite significant. The pulse rate and cardiac output begin to increase once the water temperature reaches 38°C or higher. Capillary vessels, arterioles and venues begin to dilate in the peripheral circulatory system, and increases in the volume and rate of blood flow and a decrease in systemic vascular resistance are noted. This reduces loads on the heart since dilation of the venous system reduces the cardiac pre-load as a result of an increase in the venous blood pool and decrease in the venous return. The use of thermal waters in hot pots is thus useful for relaxation and treatment of some nervous disorders.
Treatment with geothermal waters also proves beneficial against disorders of the digestive tract. The geothermal waters contain various mineral salts (the most important of these being bicarbonates), which find excellent application as drinking cures. Sodium chloride waters may be used for female disorders, with very favourable medical results. Iodine can be absorbed by sebaceous gland. Carbon dioxide and hydrogen sulphite affect the microcirculation in the body, markedly dilating peripheral vessels and enhancing vascular motion.
The therapeutic importance of the mineral solutes and gases carried in natural waters from springs and bore holes have been mentioned by many [1]. Calcium, magnesium, sodium, chlorides, and sulphates are ones most common to waters considered to have therapeutic properties. Carbonated waters are used primarily to treat cardiovascular disorders, alkaline waters are recommended for some gastrointestinal and urological disorders.

Balneological classification of mineral waters.
In the context of this report, mineral rich waters are defined as waters having beneficial effects on health. Making use of these minerals will, therefore, be important to the curative effect and its classification will only be of interest in as much as it will group together mineral

waters having similar therapeutic uses. It would, therefore, seem logical to classify according to therapeutic uses, such as waters active on the digestive system, waters active on the cardio-vascular system, etc. Most often experiments have shown the mineral waters act on the major physiological regulatory functions of the organism such as affecting the nervous-vegetative equilibrium, the calcium metabolism, etc. It is fitting to say that the associate materials of mineral waters (mud and gas) can also have significant medical use and that knowledge of them is, therefore, important. Table 1 [4] features the principal physiological properties and principal medical use of different kind of mineral waters.

TABLE 1: Balneological effect according to chemical classification of geothermal mineral waters

Chemical type of mineral waters	Principal physiological properties	Principal medical use
Bi-carbonated waters	Stimulating action on the hepatic and intestinal function, on certain general metabolism (excretion of uric acid, hypo-glycemiating effect)	Gastro-intestinal illness. Hepatic insufficiency. Gout.
Sulphated waters	Stimulating action on the billary and intestinal function. Diuretic action gastro-intestinal illness	Hepatic insufficiency. Problems with accumulation of organic waste.
Sodium chlorinated waters	Stimulating action on the growth and of cicatrisation (osseous tissue in particular)	Podiatry. After effects of osteoarticular traumatisms. Chronic infections of the mucous membranes.
Sulphurated waters	Trophic effect on the skin and mucous membranes. Antalgic, antispasmodic action.	Chronic infections of the mucous membranes. Rheumatology. Spasms (digestive in particular). Metabolic illness.

Geological settings.

Latvia is located in the western part of the East European Platform and thus characterised by the occurrence of almost horizontal sediment layers. These geological features have resulted from the non-uniform character of the directions and amplitudes of the crustal tectonic movements. The pre-Baikalian tectonic cycles have influenced the structure of the crystalline basement only, while the sedimentary cover with various structural stages was formed during the following cycles. Siltstones grow in abundance to the north and east, whereas clay content is maximal in central and south-eastern Latvia. The well sorted fine and medium-fine grained sandstones are the most common lithologies of the main part of the Cambrian of western Latvia, but they dominate also the upper part of the Cambrian section in central Latvia and the northern part of eastern Latvia.

Porosity and permeability of the sandstones across the study area vary from 25-32% and 500-1100 mD in shallow setting to 0.7-5% and 0.0001 mD in the deep part of the basin, though considerable deviations from this general trend have been documented [3]. The most considerable scatter of porosity values were stated for shallow reservoirs. At the depths of 1-1.8 km porosity of sandstones and siltstones systematically decreases to 10-20%, though

locally reaching 25-30%. Magnetic susceptibility in the central part of the basin measures 5.9 $SI*10^{-5}$.
In the Southwestern part of Latvia there is situated a geothermal anomaly, which covers about a quarter of the country. The Latvian geothermal resources are concentrated in the Lower Devonian (D1km) and Cambrian (Cm2dm) aquifers in the form of low enthalpy water. Geothermal water having noteworthy thermal power and balneological properties may be obtained from Cambrian aquifers, which are located in an area of 12,000 km^2 in the Central part of Latvia at the depth of 850-1,730 m. In the Jurmala region there is an aquiclude located at a depth greater than 300m, which effectively insulates the Cambrian aquifer from other water-bearing layers.
The basin flanks are affected by cooling from meteoric water. The geothermal gradient also reflects variations in heat conductivity of the formation rocks. Aquifers have lower values of geothermal gradient (15-30 °C/km). Geothermal gradient values vary, moreover, laterally from 10 to 50 °C/km, mainly due to differences in heat flow density. Through analyses of the cross-section of the Cambrian sedimentary rocks it was concluded that the total aquifer thickness is 76,1 m and the effective one is 52,0m in the Jurmala region.

Chemical characteristics of thermal water

The water of Cambrian-Ordovician aquifer system in the study area can be characterized by very high TDS values content around 100-120 g/l (for comparison in Reykjavik the geothermal water content is about 0.213 g/l) and by HCO_3^--Cl^--Na^+-K^+-Mg^{2+}-Ca^{2+} composition while in the active water exchange zone $HC0_3^-$-Ca^{2+}-Mg^{2+} type waters prevail (Tsheban, 1975). There is an obvious gradual increase in the TDS content of the water towards the south and the water similarly changes from a HCO_3^-(HCO_3^- - Cl^-) dominated composition to a Cl^- -Na^+-(Ca^{2+}) dominated one. Still, most of the territory is dominated by chloride-type water. Salinity in the Vendian-Cambrian aquifer reaches values as high as 70 g/l. Chloride-type water is very hard (10mg-eq/l to 2000 mg-eq/l). The content such elements as (sodium, calcium sulphur) is the same or similar to those found in health resorts at the Dead See. The pH variation in Cambrian waters is between 6.0-7.2. Gas in the water has the composition: N_2 – 92% and traces of other gases. Trace elements: strontium is found but not H_2S. The total gas content is very insignificant and not more than 25 pm^3/l. This signifies that there will not be problems with the gas collecting at the highest parts of pipelines.
The chemical composition data from some of the wells (Table 2) in Latvia were checked using the WATCH (Icelandic water chemistry group) software. The ionic balance results are good - about 0.65% difference between cations and anion, which means that chemical analysis have been done correctly.
Calculated enthalpy is about 126 kJ/kg. Applying chemical geo-thermometry simulation, shows the water in equilibrium with chalcedony and that the actual temperature in the reservoir should be about 31.3°C or more. This temperature should suffice for the envisioned swimming pool, but because of the temperature losses in the well casing and in the transmission pipes, additional energy sources should be considered. Increasing the temperature decreases the solubility of the calcite and few other chemical elements.
The thermal water in the Cambrian aquifers is typically quite corrosive. Therefore some more testing on corrosion is recommended before the material for pipelines is selected.
Thermal water in the study area is characterized by high concentration of sulphate SO_4 (1200-1600 mg/l), chlorine Cl (68000-76000mg/l), bromine Br (200-300 mg/l), sodium (31000-37000 mg/l), magnesium Mg (2400-2800 mg/l) and potassium K (130-480 mg/l). Water of this composition is found to be very favourable for medical treatment and also for relaxing, rehabilitation and disinfecting of the skin and compared to waters in famous resorts it has significant advantages Table 2.

Balneological characteristics of the thermal water.

Sulphur-water baths were first installed in houses in the 18th century in study area, and doctors have exploited the mineral-rich waters since 1796. Later was discovered the curative value of the local mud. All the aquifers that yield mineral water, which might prove interesting for therapeutic utilization, as well as the sources of medical mud, have in particular been found in the western part of the Resort Jurmala – Kemeri.

As we can see from Table 2, the Cambrian aquifer is more or less uniform, and the properties of geothermal water in the geothermal anomaly nearly the same everywhere. Average total dissolved solids (TDS) value is 113 mg/l and it is at least 100 times greater than is required for this water to be specified as "mineral water". However some factors, determining the origin of mineral water in study area were categorised [6]:

- Biogenetic reduction of sulphate in the Salaspils Formation. The rate of sulphate reduction be of the order of 0.064 mg/l/day (pH = 6.7-7.2; Eh – up to 200mV);
- Dissolution of gypsum by Quaternary water permeating into the Salaspils and Plavinas formations;
- Different sedimentation ion exchange and migration processes during the Narva Basin time and later, etc.

The following types of mineral water are widely found in the vicinity of the Kemeri:

- Highly mineralised sodium chloride water containing bromine in concentration of up to 280 mg/l and total dissolved mineral content of up to 120-125 g/l. The Cambrian formation (mainly sandstone and siltstone, approximately 70 m thick) is the one most productive. During previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources – 114 m^3/day.
- Water containing hydrogen sulphide and calcium sulphate (bicarbonate of sulphate, magnesium and calcium) with sulphate content of up to 1200 mg/l. The thickness of productive Salaspils Formation (dolomite, marl, clay, gypsum) varies from 10 to 20m. In previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources exceed 300 m^3/day;
- Water containing bromide, sodium and calcium chloride–with bromide content up to 14 mg/l. Most productive is the Parnus formation (mainly sandstone and siltstone, approximately 30m thick). In previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources comprise more than 1,700m^3/day;
- Water containing calcium sulphate (bicarbonate of sulphate, magnesium and calcium) having total dissolved mineral content of up to 2.0 mg/l. Productive areas are the Salaspils and Plavinas (mainly dolomite, 15m thick) formations. This type of mineral water has never been exploited.
- Chloride calcium – sodium water containing bromine of up to 226 mg/l. Productive is Kemeri formation (mainly sandstone and siltstone, approximately 115-120 m thick). This type of mineral water also has never been exploited.

Such mineral waters are considered be good for relaxation, treatment of nervous-muscular problems, and poly-arthritis, infertility and skin problems like psoriases. Such water is moreover beneficial for disorders of the neurological system such as post infection (meningitis, encephalitis, etc.), post stroke, spinal cord post traumas injuries, disorders of the peripheral neurological system, complications vertebral - spinal disorders. It is also used for disorders of the stomach, liver, pancreas and intestines function, disorders of the kidneys, bladder and urinary systems function, prostate problems, arthritis (joint pain), high blood

pressure, post surgical intervention, post heart attack, angina pectorals (chest pain), heart malformation. Because of high TDS content in the water it is assumed to be very suitable for recreational exercises, easy for moving and swimming in.
The quantity of exploitable medical mud, mostly found in the "Sloka" (near Vaivari and Kudra) area, and is some 362,000 m^3. It is important to underline here, that medical mud can be used repeatedly after being rejuvenated. The natural rejuvenation process takes 1.5 – 2.0 years, and takes place in ponds that are specially constructed for the purpose. Jurmala Resort development, must be based on utilisation of different types of available mineral water and medical mud resources these. The possibilities of bromine extraction from the Cambrian Aquifer should also be investigated. The currently available data indicate that this thermal water can also be used for health problems such as external wounds, diabetes, gout, circulation problems, bronchial problems, gallstones, hardening of the arteries, palsy, haemorrhoids, neuralgia, rheumatism, neurosis, obesity, skin problems. The State Company "Latvijas Geologija" has started collating a database of mineral water composition and resources that may be used for medical and industrial purposes [6]. The mapping of hydro-geochemical conditions and country-wise distribution of the various types of mineral water of Latvia will be undertaken simultaneously.

Closing remaks.

- Geothermal mineral water contained in sedimentary layers of Cambrian aquifers compares favourably with the water in famous Health resorts that have proven balneological properties.
- The utilisation of low-temperature geothermal fields in Riga/Jurmala region is commercially profitable only if it encompasses utilisation of the balneological properties of the thermal water.
- There are "free windows" in Latvian tourist business (not a single outdoor thermal swimming pool in the main tourist centers of Latvia), which it would be beneficial to "fill" for future growth of Latvian economy.

The environmental policies of today are moving towards atmospheric pollution taxes being levied on energy producers using conventional fuels and trade in pollution quotas. These measures will undoubtedly affect energy prices in a way that enhances the viability of geothermal energy developments and makes them a more politically attractive alternative. Government support needs to be solicited because it will greatly facilitate the development of such geothermal developments as health spas (using the extremely mineral rich geothermal waters of Latvia).

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TABLE 1 : Chemical analysis comparison of the geothermal water in wells in Latvia and in famous resorts.

Fluid chemical composition of the water for selected wells in Latvia								**Fluid chemical composition of the water in the famous resorts** [1]						**Sea water**
Town, Well no.	**Units**	**Jurmala R1**	**Jurmala R2**	**Jelgava 2**	**Bauska 1**	**Dobele P44**	**Baldone 80**	**Blue Lagoon**	**Dead See**	**Tiberias**	**Hamei Yoav**	**BaTh**	**Baden -Baden**	
pH		5.8	6.4	6.2	5.9	6	6.1	7.37					8.2	
TDS	g/l	114.3	111.5	117.6	123.9	115.1	119	24.4	310	26	2.6	0.9	3.1	35.82
K	mg/l	440	440	-	-	-	445	1030	7560	291	15	15.4	32.9	392
Na	mg/l	33055.6	31831.8	34074.5	36518	32972.8	34679	6910	34940	5600	800	177	851	10800
Ca	mg/l	7214.4	6973.9	7128.2	7012	7320	6881.7	1100	15800	2752	113	392	144	411
Mg	mg/l	2480.8	2723.8	2739.6	2770	2602.2	2585.2	0.81	41960	595	66	51	58	1290
Cl	mg/l	70000	68400	71800	75600	70400	72600	13550	208070	15051	1566	277	1442	19400
Br	mg/l	290	215	271.7	298.3	283.8	271.7	44.5	5.6	133	4		1.6	67.3
Fe	mg/l	10	10.6	12.6	5.8	10.4	7.4	-	-	-	-	-	-	3400
Mn	mg/l	0.03	0	0	0	0	0	-	-	-	-	-	-	0.0004
Cu	mg/l	0.001	0.002	0.005	0	-	0	-	-	-	-	-	-	0.0009
Si	mg/l	-	-	-	-	-	-	219	-	-	-	-	167	-
SO4	mg/l	1243.2	1282.9	1532.1	1581.4	1438.7	1517.6	31	0.5	695	22	1	209	-
HCO3	mg/l	30.5	24.4	30.5	42.7	30.5	36.6	-	-	-	-	-	-	-
Al	mg/l	0.08	0	0.35	0.15	0	0.15	-	-	-	-	-	-	0.001
Zn	mg/l	0.005	0	0	0	0	0	-	-	-	-	-	-	-
Pb	mg/l	0.02	0.04	0.05	0.025	0.03	0	-	-	-	-	-	-	0.00003
N2	Vol. %	92.5	89	95.4	94.5	-	-	-	-	-	-	-	-	-
CH4	Vol. %	0.02	0.02	0.045	0.043	-	-	-	-	-	-	-	-	-
C2H6	Vol. %	0.0002	-	0.0002	0.0001	-	-	-	-	-	-	-	-	-
CO2	Vol. %	0.2	0.81	1	1.05	-	-	35.9	240020	-	-	193	20.4	-
H2S	Vol. %	0	0	0	0	-	-	0	-	-	-	-	-	-
He + Ne	Vol. %	1.81	4.09	2.1	2.81	-	-	-	-	-	-	-	-	-
Ar + Kr	Vol. %	0.381	0.62	0.567	0.47	-	-	-	-	-	-	-	-	-
H2	Vol. %	5.08	3.7	0.91	0.923	-	-	-	-	-	-	-	-	-
C3H8	Vol. %	0.0001	-	0.0002	0.0001	-	-	-	-	-	-	-	-	-
O2	Vol. %	0	1.12	0	0.2	-	-	-	-	-	-	-	-	-