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Extended Abstracts

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4.2
Origin of mineral and thermal waters

title: **Factors of thermomineral groundwater origin at
Josanicka banja spa, Central Serbia**

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The Josanicka Banja Spa is situated in central part of Serbia on slopes of Kopaonik Mountain. It is characterised by significant thermo mineral resources, both as to quality and quantity ($Q > 15$ l/s, T up to 79°C). The occurrence of thermo mineral waters in the territory of the Josanicka Banja Spa is related to the young (Neogene) magmatism and tectonic activity taking place in the Kopaonik region.

Qualitative characteristics of the Josanicka Banja Spa thermo mineral water have been formed in various geological, hydrogeological, geochemical and hydro chemical, processes in co action of water, rocks and gases. Factors of thermo mineral water formation can be both the main and auxiliary ones, or direct and indirect. Factors affecting the formation of thermo mineral groundwaters in the Josanicka Banja Spa are presented in Table 1.

Table 1. Factors affecting the formation of thermo mineral groundwaters in the Josanicka Banja Spa.

| FACTORS OF THERMOMINERAL WATER FORMATION IN JOŠANIČKA BANJA SPA | | | | | |
|---|------------|-----------------|----------------------|----------|------------|
| PHYSICO- GEOGRAPHICAL | GEOLOGICAL | HYDROGEOLOGICAL | PHYSICO- CHEMICAL | PHYSICAL | ARTIFICIAL |

Physico-geographical factors. The separated relief in the Josanicka Banja Spa region conditions more intensive water exchange, which is favourable to the formation of low mineralized water ($M \sim 0.2$ g/l). A thick hydrographic network is favourable to the intensive process of water exchange in water-bearing horizons, which conditions the formation of low mineralized waters ($M \sim 0.2$ g/l). Climatic elements (precipitation, air temperature, and evaporation) do not affect the formation of the chemical composition of the Josanicka Banja Spa thermo mineral water significantly.

Geological factors The Kopaonik region, to which the Josanicka Banja Spa also belongs, is characterized by heterogeneous geological structure. It is made of igneous, sedimentary and metamorphic rocks of varied ages, from the youngest Quaternary alluvial placers of the Josanica River to the oldest Palaeozoic slates. Tectonic movements having taken place in the Josanicka Banja Spa region resulted in a large number of faults, creating a favourable predisposition for the formation, circulation, and discharging of thermo mineral water in the Josanicka Banja Spa region.

Hydrogeological factors The complex geological structure and setting of the study area have conditioned the formation of various aquifer types. In the Josanicka Banja Spa region, on the basis of structural type of porosity, there have been singled out the following aquifer types: a compact aquifer, within alluvial sediments of the Josanica River, a fissure aquifer, and a karst-fissure (complex type) aquifer. Thermo mineral groundwater in the Josanicka Banja Spa region was formed within a fissure aquifer. This aquifer type has been developed in igneous (granodiorite, and quartz-diorite, harzburgite) and metaphoric rocks (phyllite, chlorite-epidote-actinolite shale and serpentinite). of which the Josanicka Banja Spa region is mostly formed. A tectonic activity taking place in the Kopaonik area resulted in numerous faults. Two faults are most pronounced in the Josanicka Banja Spa region. The first one stretches along the valley of the Josanica River striking east-west, while the other one is vertical in relation to it, and goes along the valley of the Velestica River striking north-south. At the spot of the crossing of these two faults, there is a seepage spring of thermo mineral water characterised by thermomineral water temperatures ranging from 76°C to 78°C . Going westward from the mentioned spring, the temperature of thermomineral water decreases, thus in the B-3 and B-6 abstraction boreholes

situated about 500 m from the thermomineral springs in the centre of the Josanicka Banja Spa the temperature of groundwater ranges from 52–56°C, while at the distance of about 2 km west of the spring in the Josanicka Banja Spa, at the Slaniste locality, the thermo mineral water is characterised by the water temperature ranging from 36 to 37°C. The formation of thermo mineral water qualitative characteristics in the Josanicka Banja Spa region is related to younger deep-seated igneous and, by their activity, caused thermo metamorphic processes having taken place in the Kopaonik area during Neogene. The thermo mineral waters of the Josanicka Banja Spa (according to the classification by Ivanov, 1977) belong to the group of *nitrogen low mineralized silicon thermo mineral waters of atmospheric origin*. These waters are genetically related to massive crystalline rocks, within which hydrogeologically uncovered fault structures, enabling the infiltration of the waters of atmospheric origin and their warming at higher depths, are readily formed and long preserved. Waters formed in such conditions are characterised by low mineralization from 173.8 to 256.4 mg/l, with the prevailing sodium ion, the high content of silicon acid (32 to 90 mg/l) and a pronounced alkaline reaction (pH from 8.4 to 9.7). Analyses of qualitative properties of thermo mineral waters were carried out in four locations in the Josanicka Banja Spa (Tab. 2).

Table 2. Survey of qualitative properties of thermo mineral waters in Jošanička Banja Spa region.

| Occurrence/ Parameter | Q (l/s) | T (°C) | pH | M (mg/l) | Na ⁺ (mg/l) | CO ₃ ²⁻ (mg/l) | SO ₄ ²⁻ (mg/l) | Cl ⁻ (mg/l) | F ⁻ (mg/l) | SiO ₂ (mg/l) | H ₂ S (mg/l) |
|--------------------------|------------|-----------|------|-------------|---------------------------|---|---|---------------------------|--------------------------|----------------------------|----------------------------|
| Jošanička spring | 15 | 76–78 | >8.4 | 243.9 | 89.0 | 60 | 60 | 14 | 4.48 | 90 | 1.50 |
| Slanište spring | 2 | 36–37 | >8.4 | 256.4 | 98.0 | 60 | 70 | 28.4 | 5.6 | 90 | 0.12 |
| B-3 borehole | 1.5 | 52 | >8.4 | 173.8 | 71.5 | 66.0 | 15.0 | 21.3 | 4.4 | 32 | 1.02 |
| B-6 borehole | 3 | 56 | 9.7 | 185.0 | 63.4 | 54.6 | 32.4 | 10.1 | 3.75 | 79.5 | 2.1 |

Physico-chemical properties. The migration ability of elements (Na, Li, and F) depends to a large extent on the pH index. If we increase the temperature, the pH index of deposited hydroxide increases (to 9.7). The solubility of a salt plays a significant role in the formation of anion – cation composition. Thus, a sodium ion, a carbonate ion, and a silicon ion occur as characteristic ones for low mineralized waters (from 183 to 256.4 mg/l).

Physical factors. As the temperature increases, the ability of solubility changes. In ordinary conditions the solubility of silicon acid is highly low. At high temperatures silicon–carbonate–sodium–waters often occur, which is the case with Josanicka Banja Spa waters. As the temperature increases, the pressure increases as well, which affects the ability of water for solubility to a significantly lesser degree?

Artificial factors. By monitoring of thermo mineral water exploitation at the abstraction boreholes (B-3 and B-6) in the Josanicka Banja Spa, the trend of the yield decrease is observed (B-3 from 3 l/s to 1.5 l/s, B-6 from 7 l/s to 3 l/s, after more than 25 years of exploitation). On the other hand, the exploitation of many years has affected the temperature increase (B-3 from 50 to 52, B-6 from 52.5 to 56).



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