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**Development of a concept for the use of unique mineral healing waters of the Zuber type in order to range of expand the balneotherapy in the Krynica-Zdrój health resort**

SUMMARY OF THE DOCTORAL THESIS

The main objective of the implementation project was to develop a concept of using the unique therapeutic waters of the Zuber type in order to expand the range of balneotherapy in the Krynica-Zdrój Health Resort.

For this purpose, it was extremely important to recognize the hydrogeochemical and thermodynamic processes that determine over 100 years of exploitation of gasified waters from the Zuber I, Zuber II, Zuber III and Zuber IV wells, as well as to understand the complex processes of formation of therapeutic Zuber waters, the origins and location under specific geological conditions or the specifics of exploitation. This required a thorough analysis of geological data: including hydrogeological and hydrogeochemical data, both published and archival.

A detailed analysis of isotopic tests of both water and gas was a key element in understanding the origin and identification of the processes shaping the physicochemical or molecular composition of raw materials obtained from the Zuber I, Zuber II, Zuber III and Zuber IV wells.

An important element of the work was also the characteristics of the concentrations of potentially harmful components in water and gas. Their presence in the medicinal raw material is of great importance when it is used for balneotherapeutic purposes.

All available, i.e. over 160, archival physicochemical analyses were compiled in order to fully present the picture of the variability of the physicochemical composition of Zuber-type healing mineral waters. As part of this work, stationary tests performed as part of the functioning of the Health Resort Mining Plant were used. Each time, such tests include the measurement of temperature, pH, CO<sub>2</sub> concentration with a "Karat" apparatus, as well as the determination of the HCO<sub>3</sub> ion and, in justified cases, the Mg

ion. They also include a comprehensive measurement of the efficiency of Zuber intakes and gas production measurement periods.

Gas measurement is carried out using bellows type BK gas meters (usually used for natural gas), with the selection of the inflow  $Q_{max} > 50\text{m}^3/\text{h}$ . Due to the water content of the gas, a high frequency of gas meter replacement was used in order to obtain the most reliable data.

As part of the implementation project, the health resort also modernized the water-gas separation system and the storage and measurement system. These works lasted several years due to the significant investment cost and included not only changing the materials used for the construction of storage and measurement tanks, but above all testing the effectiveness of water-gas separation with the use of separators and the so-called. "organs", i.e. a system of pipes of different diameters, connected in series, which were intended to create a back pressure for the emerging gas and direct it to the pipeline discharging to the CO<sub>2</sub> plant.

As part of the implementation project, an automatic system for the exploitation of the Zuber IV well was implemented, based on a choke with a diameter of 5.5 mm, for 6h/d of production. The selection of appropriate parameters enabled the maximum daily extraction of the main raw material and increased the exploitation capacity of the accompanying mineral, which will be of great importance for increasing the spa's balneotherapy activity. The conducted research shows that it is possible to increase production on this well without detriment to the exploitable resources.

At the stage of further research conducted by the author of the project, the optimization of operating parameters for the Zuber I, Zuber II and Zuber III wells remains to be optimized, while research on the Zuber I well has been discontinued for the time being.

Observations of the operation of the Zuber I intake with the designed diameters of the venturi tube will be possible after the renovation of the operating intake gate valve and obtaining the appropriate certificates. This is important as 2 1/16" (x14Mpa) gate valves are no longer manufactured. The need to install a new valve or the certification of an existing one for a short period will cause the optimization work to start anew. Installation of a new gate valve involves the replacement of the entire system: replacement of the block, side valves: relief and injection, as well as operational: production and emergency valves.

A change in the way of storing Zuber-type medicinal mineral waters was

designed and implemented, which significantly influenced the quality of Zuber-type medicinal waters made available for balneotherapy purposes. The old Zuber-type therapeutic water storage reservoirs were decommissioned in order to reduce bacteriological contamination, and in the case of storage of medicinal waters from the Zuber II well, in order to get rid of the interesting, but undesirable phenomenon of blue water. In addition, qualitative and quantitative observations of the released sediments helped the author of the project in selecting the appropriate materials, such as acid-resistant stainless steel with the symbol 316L, enabling trouble-free use of all the solutions applied. The exploitation of therapeutic mineral waters of the Zuber type is associated with a number of technical problems. Both the mineralization of these waters and the coexisting sediment in the form of clay-sludge suspension and accompanying gas cause significant corrosion of surface equipment. The water and gas conditions require complex and specific operating conditions, and thus a separation system as well as storage and measurement devices, the system for which has been designed exclusively for the Zuber well.

The data received are sufficient to carry out the further part of the implementation project, which is the modernization of the gas cleaning process for the Zuber wells.

This work entitled "Developing a concept for the use of unique therapeutic waters of the Zuber type in order to expand the balneotherapy range of the Krynica-Zdój health resort" is one of the tasks for the execution of a multi-purpose implementation project carried out as part of the Krynica-Żegiestów S.A. Health Resort called "A prototype of a natural carbon dioxide treatment plant supporting the mineralized water production system in the Krynica-Zdrój health resort together with the modernization of the "Zuber" therapeutic water intake system and a natural carbon dioxide treatment installation supporting the mineralized water production system in the Krynica-Żegiestów S.A. health resort. along with the reduction of CO<sub>2</sub> emissions into the atmosphere."

This is a further part of the research carried out within the CO<sub>2</sub> plant, which will translate into increased storage and management of this gas. Currently, CO<sub>2</sub> is used in and outside the spa, mainly balneotherapy, in which cryotherapy is currently the most popular treatment, and also for bottling purposes.