Heat potential of the Upper Jurassic-Lower Cretaceous aquifer in Central Northern Bulgaria: conditions and prospective use

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Introduction

In recent years, the use of renewable energy, including geothermal energy, has been extensively increasing globally in accordance with the documents adopted by the global forums on climate and sustainable development. The geological setting of Bulgaria provides conditions for the formation of thermal waters that could be used as energy sources. The hydrothermal resources have been evaluated to 9957 Tj/a and they are not being sufficiently utilized. Considering that the temperature of most thermal waters in Bulgaria are up to 100ºC, so far these resources have not been used for electricity production. The aim of the present study is to evaluate the potential for heat extraction and the possibility for heat production from the thermal reservoirs formed in the deep parts of artesian aquifers.

FORMATION OF THERMAL WATERS IN THE STUDY AREA

Geologically, Northern Bulgaria is within the expense of a platform structure, which forms a large and complex artesian basin. It is set up by deep aquifers separated by aquitards. In this sequence, the Upper Jurassic-Lower Cretaceous aquifer has the largest area, greatest thickness and it is the most water abundant. This aquifer has limited outcrops in its southern part and within the area of the so-called North Bulgarian Uplift in Northeastern Bulgaria. From there, it gradually dips to over 4000 m depth in Northwestern Bulgaria. The main groundwater reservoir is a carbonate complex of limestone and dolomite, whose high water permeability and high yield are the result of active palaeokarst processes. The thickness of the aquifer is in the range of approximately 700 m to 1500 m, except for the outcrop zones in its southern part, where it abruptly decreases to about 100-200 m due to facies transition.

The hydrodynamic parameters vary within a very broad range, which results in quite specific conditions for heat accumulation and potential for extraction in the different parts of this aquifer. High transmissivity is typical for its eastern part, where the highest recorded values are above 3000 m²/d.

The transmissivity decreases to approximately 40 m²/d to the west and southwest. As a rule, high transmissivity and yield correlate to lower geothermal gradient. Previous studies identified low values of the geothermal gradient within the aquifer – between 1°C/100m and 2.5°C/100m, which is related to its relatively high yield. The highest values are found in the deep southwestern part of the aquifer, characterized by the least degree of karstification and where convective heat transfer is inhibited. With the top of the aquifer dipping from east to west/southwest, the groundwater temperature increases - from around 40ºC and less, in the near surface eastern part of the study area, to above 100ºC in its southwestern part, at depths below 3000 m.

In the confined eastern part of the aquifer, there are chloride-sulphate-sodium-calcium and chloride-sulphate-sodium types of water with total mineralization between 1.55 g/l and 10 g/l. With increasing depth, the water type changes to sodium-chloride, and the mineralization increases to above 20 g/l, which is the reason for considerable deposition of minerals in the course of thermal water abstraction.

METHODS

The study was performed in the following sequence: (i) evaluation of the static groundwater reserves in the thermal water reservoir; (ii) determination of the regional density-dependent groundwater flow; (iii) drawing a groundwater temperature map on a regional scale; (iv) differentiating sections and blocks of relatively homogeneous properties; (v) calculation of the renewable groundwater resources and energy reserves by sections; (vi) evaluation of the regional reserves of heat energy in the blocks for the abstraction by reinjection systems; (vii) economic valuation of reserves by blocks and by sectors.

Regional heat reserves extractable by reinjection systems were evaluated by applying an innovative method that was developed and approbated for the overall evaluation of the heat reserves in Bulgaria by a team of the Geological Institute at the Bulgarian Academy of Sciences. In summary, the approach is as follows: the thermal water reservoir is divided into blocks with average values for temperature θ, transmissivity T, aquifer thickness m, and total groundwater resources Qsum. The area of each block is covered by well doublets with equal circulation rates Qs, whereas the abstraction and reinjection wells are being distributed in a checkered pattern, spaced at equal distances δ. The total groundwater resources in each block is calculated by summing up its renewable groundwater resources and static groundwater resources. The yield of each well doublet is Qs = Qsum/n, where n is number of doublets in a block.

RESULTS AND DISCUSSION

The thermal power extractable by reinjection system Qs, was calculated by assuming that the defined well doublets in the four blocks operate at yields Qs and Qsum (Table 2). The total number of doublets n is 3700, which corresponds to 900, 1250, 800, and 750 for the individual blocks A, B, C, and D. The projected depressions in the abstraction wells are between 5 m and 30 m and the transit time for breakthrough of re-injected water vary between 50 and 350 years. For each block, the Qs values (per annum) were calculated at 15°C temperature drop in reinjection systems and are listed in Table 4, whereas the established relationships between thermal power W, and temperature difference δθ.

CONCLUSION

Based on the results of the study, the following conclusions can be made about the potential heat extraction from the Upper Jurassic-Lower Cretaceous aquifer in the considered region:

(i) The heat resources are estimated to 8184 Tj (per annum). Converted to equivalent fuel this makes 195509 t oil, or approximately 11.73 million USD.

(ii) The total heat extractable by reinjection systems Qsum, amounts to 303993 TJ/a, which expressed as equivalent fuel equates 7262136 t oil for approximately 435.7 million USD.