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A GIS-based method for analysis of a better utilization of thermal-mineral springs in the municipality of Kursumlija (Serbia)

Aleksandar Valjarević[a,b,*], Danica Srećković-Batoćanin[c], Dragana Valjarević[d], Vesna Matović[c]

[a] Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Vietnam
[b] Faculty of Environment and Labor Safety, Ton Duc Thang University, Ho Chi Minh City, Vietnam
[c] Univeristy of Belgrade, Faculty of Mining and Geology, Serbia, Djusina 7, 11000 Belgrade, Serbia
[d] University of Kosovska Mitrovica, Faculty of Science and Mathematics, Department of Mathematics, Lole Ribara 29, 38220 Kosovska Mitrovica, Serbia

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ABSTRACT

There are about 240 geothermal occurrences with 60 commercial spas included in, which are spread throughout the territory of Serbia. The majority of springs and other surface manifestations are located along the south-eastern edge of the country. Three spas Lukovska, Prolom and Kursumlijska are with the highest geothermal potential and balneology utilization. They are situated in the vicinity of Kursumlija, one of the largest municipalities in Serbia, but with poor economic development. Although the presence of these three spas and more than 23 thermal mineral springs with the temperature of water between 26.4° and 68 °C reveal it among the great geothermal resources in Serbia, the extent and potential of these resources are poorly understood. The estimated capacity of geothermal energy in three spas and 20 springs is 620.36 (TJ/year) or 19.6 MWt. In spite of a vast quantity of this clean, renewable energy resource only a small percentage of it is used in balneology and extremely rarely for greenhouse heating. In Serbia the kind of energy mostly used belongs to dirty energy resources, such as timber, coal, oil, gas, natural gas, etc. The use of geothermal renewable energy for the heating of public institutions is highly recommendable and agrees with today's growing awareness of the environment protection and improvement of the quality of life. The additional use of it for heating in householders would reduce the import of natural gas and oil and would support the municipality and its inhabitants to escape from poverty.

1. Introduction

The territory of Serbia covers an area of 88,407 km^2 in the central part of the Balkan Peninsula in the south-east Europe (Fig. 1). The main cities are Belgrade (capital), Novi Sad and Niš. In Serbia, a large number of geothermal occurrences, i.e., about 240 thermal-mineral springs (abbrev. ThM) with the temperature of water exceeding 15 °C and 60 commercial spas included in, has been identified. The sources of the highest temperature occur in the south: Vranjska Spa (96 °C), Josanicka Spa (78 °C), Sijarinska Spa (72 °C), Kursumlijska Spa (68 °C), Lukovska Spa (67 °C), etc. The average geothermal capacity in Serbia is estimated to surpass the mean value in Europe (< 100 mW/m^2) [1], and the total discharge exceeds 4500 l/s [2–4]. The study of the genesis, chemical and physical properties of mineral and thermal-mineral waters in Serbia has been employed for more than 150 years. The first scientific supported investigations of geothermal energy systems refer to the book"Ground Water", which was published by Radovanović as early as in 1897 [5]. Radovanović is recognized as the pioneer of hydrogeology and geothermology, and he emphasized the unavoidable link between geology, chemistry, and medicine in his studies. Excluding Radovanović and following some established principles a few scientists gave a chemical and physical characteristics for dozens of spas in the Kingdom of Serbia, as well of the Kingdom of Yugoslavia [6,7] The first detailed approach to water genesis and content of microelements in thermal waters in Serbia gave Vujanović and Teofilović in 1983 [8]. A Complete, but generalized report of geological, hydrogeological, geochemical, thermal and balneological data is given in the form of book,- Mineral and thermal waters if Serbia" by Protić in 1995 [3]. The distribution of ThM and their importance for the human health reported Teofilović. In 1992. Babović published a book that explains in more

Abbreviation: ThM, Thermal-mineral spring; SMM, Serbo-Macedonian Massif; KBR, Kopaonik block and ridge; QGIS, Quantum Geographical Information System; SAGA, Extension of Spatial Analyst

* Corresponding author at: Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Vietnam.
E-mail addresses: aleksandar.valjarevic@tdt.edu.vn (A. Valjarević), danica.sreckovic@rgf.bg.ac.rs (D. Srećković-Batoćanin), dragana.valjarevic@pr.ac.rs (D. Valjarević), vesna.matovic@rgf.bg.ac.rs (V. Matović).

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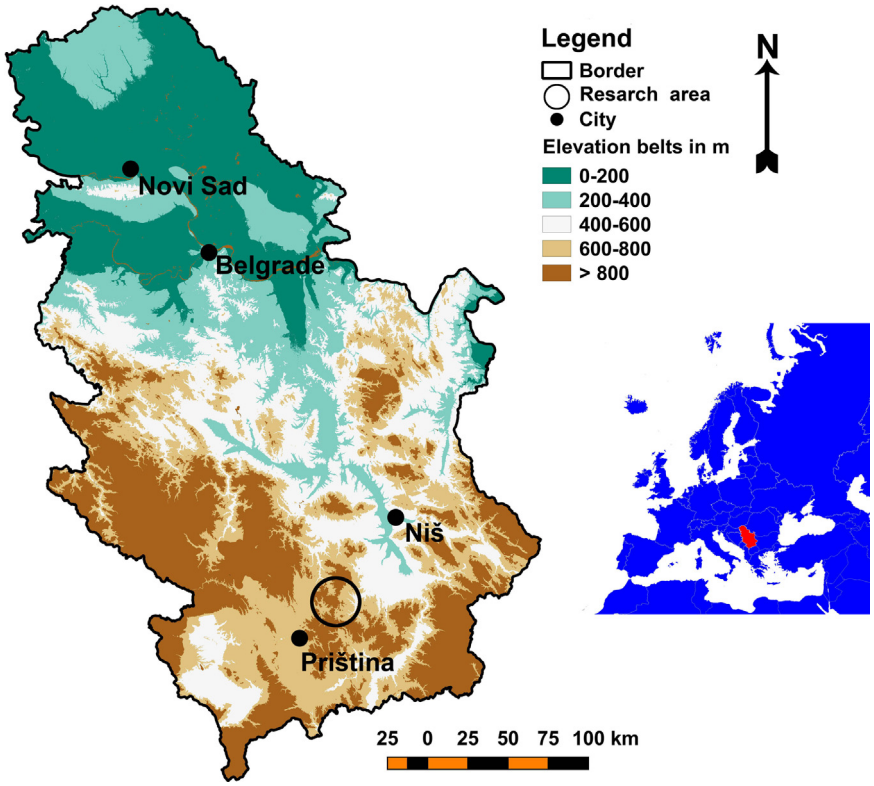

Fig. 1. Position of Serbia in the world and the view of the main cities, as well investigated area.

detail the inevitable connection between geology [9], ThM and environmental protection, and their combined influence on the human health. The studies of ThM in Serbia have been intensified recently, particularly after the first oil crisis in 1974, leading to the recognition of the geothermal energy as the priority of the sustainable development in the Republic of Serbia [10]. The new opportunities in an exploitation of energy resources and sustainable development have become obligatory. The sustainable energy includes renewable energy sources, such as hydroelectricity, solar energy, wave power, bioenergy, tidal power and geothermal energy. The high geothermal potentials in Serbia, particularly along the southern edge of the Pannonian Basin, and in the southeastern and western part of Serbia have been utilized mostly for balneological purposes, rarely for space heating. For better planning in sustainable development and environmental protection, new clean energy resources need to have a more significant role. The areal distribution of ThM as well as of the established spas should be considered regarding the main geotectonic units in Serbia: Carpatho-Balkanides and the Dacian basin on east, Sumadija-Kopaonik, and Serbo-Macedonian mass in a central part of Serbia, the Dinarides in the west and finally, the Pannonian Basin in the north. Numerous thermal-mineral springs in Serbia are the result of complex geological evolution, which revealed rocks of different age and genesis and different properties. Thus the water quality has formed through the interaction of water with highly different rocks, ores,soils and suspended sediments. The majority of all of the presently known geothermal sites in Serbia are stored within the porous Tertiary sediments in the Pannonian Basin in the Vojvodina Province. Elsewhere in Serbia, a convective hydrogeothermal areas appear in terrains built of solid rocks of Tertiary, Mesozoic, Paleozoic, even of Pre-Paleozoic age that display characteristically high porosity [11]. Spatial distribution and geothermal characteristics are consistent with the variability of a depth of faults that increases in the north-south direction in Serbia, as has been confirmed by studies in the Bačka region in the Vojvodina Province [12]. Faults in the Pannonian Basin in the Vojvodina Province are of a uniform depth, about 25–29 km. Inside the Dinarides faults attain depths of 40 km, in Serbo-Macedonian mass up to 32 km, while in the Carpatho-Balkanides these depths range from 33 to 38 km. Geothermal springs inside the Dinarides and Carpatho-Balkanides are of the higher discharge than those in the Pannonian Basin. The majority of ThM are situated either at depths between 200 and 400 m or at elevations exceeding 500 m. The highest is the springs draining Mesozoic karstified limestones and those related to Tertiary granitoids and volcanic rocks [13–16]. According to the water temperature, mineral springs could be classified into mineral springs with temperature beneath 20 °C and those with temperature exceeding 20 °C [17,18]. Additionally, (ThM) springs were divided into three independent groups according to the value of their temperatures: low (water temperature between 20 °C and 34 °C), moderate (temperatures between 34 °C and 38 °C) and high (temperatures exceeding 38 °C). Along with the 60 established spas, there are more than 100 unofficial or folk spas in the territory of Serbia, revealing it a name a spa-country [19]. But that health and clean environmental potential are not used enough. According to the estimated potential capacity of geothermal energy of about 800 MWt, Serbia is among the top 35 countries in the World. Unfortunately, only about 12% (around 100.9 MWt) is exploited for energy purposes Thermal and mineral waters from spas in Serbia, medicinal mud and radioactive gases have been used in disease treatment for more than 2000 years, whereas the exploitation of (ThM) water has much longer history [20,21]. The first records of spas in Serbia date back in the Middle Ages and the Roman Empire. Modern studies of (ThM) springs from geological aspect are a part of searching for renewable energy sources, which are without negative consequences for the environment [22]. The investigation of spas in Serbia reflected on unique and distinct physical and chemical characteristics of (ThM) waters and high potential for the geothermal renewable energy of the studied (ThM) sources, particularly in the southeastern part of the country (Kursumlija Municipality) [23–26]. The Municipality of Kursumlija is located in the central-east part of South Serbia. It is surrounded by Brus, Blace, Prokuplje and Medvedja Municipalities and it partly borders Kosovo. The total number of settlements is 19,213 inhabitants (2011 Census). The distance from the