Chemosphere 242 (2020) 125171

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Spa environments in central Serbia: Geothermal potential, radioactivity, heavy metals and PAHs

Ljiljana Gulan [a], Ivana Penjišević [a], Jelena M. Stajic [b], Biljana Milenkovic [b], Tijana Zeremski [c], Vladica Stevanović [a], Aleksandar Valjarević [d, e, *]

[a] Faculty of Sciences, University in Priština-Kosovska Mitrovica, Lole Ribara 29, 38220, Kosovska Mitrovica, Serbia
[b] Institute for Information Technologies Kragujevac, Department of Science, University of Kragujevac, Jovana Cvijica bb, 34000, Kragujevac, Serbia
[c] Institute of Field & Vegetable Crops, Maksima Gorkog 30, 21000, Novi Sad, Serbia
[d] Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Viet Nam
[e] Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Viet Nam

HIGHLIGHTS

- Medium or low thermal potential of spas with total power of 0.025 MW was estimated.
- High radon concentration from Sokobanja water samples was detected.
- As, Cr, Ni and Hg in soil exceeded the regulatory limits.
- More than a third of soil samples were contaminated with PAHs.

ARTICLE INFO

Article history:
Received 30 June 2019
Received in revised form
8 October 2019
Accepted 20 October 2019
Available online 22 October 2019

Handling Editor: Martine Leermakers

Keywords:
Geothermal potential
Radioactivity
Heavy metals
PAHs
Risk assessment

ABSTRACT

This study aims to estimate geothermal potential, radioactivity levels, and environmental pollution of six most popular spas in Central Serbia (Ovčar, Gornja Trepča, Vrnjačka, Mataruška, Bogutovačka and Sokobanja), as well as to evaluate potential exposure and health risks for living and visiting population. Thermal possibilities of the studied spas showed medium and low geothermal potential with total thermal power of 0.025 MW. Gamma dose rates in air varied from 63 to 178 nSv h^{-1}. Specific activities of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) and ^{137}Cs in soil were measured; annual effective doses and excess lifetime cancer risk from radionuclides were calculated. Radon concentration in thermal-mineral waters from the spas ranged between 1.5 and 60.7 Bq L^{-1} (the highest values were measured in Sokobanja). The annual effective dose from radon due to water ingestion was calculated. The analyzed soils had a clay loam texture. The presence of As, Cr, Cu, Fe, Mn, Ni, Pb, Cd, Zn, and Hg in soil was investigated. The concentrations of As, Cr, Ni, and Hg exceeded the regulatory limits in many samples. Soil samples from Mataruška spa were generally the most contaminated with heavy metals, while the lowest heavy metal concentrations were observed in Sokobanja. Health effects of exposure to heavy metals in soil were estimated by non-carcinogenic risk and carcinogenic risk assessment. Total carcinogenic risk ranged between 6×10^{-4} and 137×10^{-4} for children and between 0.1×10^{-4} and 2.2×10^{-4} for adults. The sum of 16 PAHs analyzed in soil samples varied from 92 to 854 μg kg^{-1}.

* Corresponding author. Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Viet Nam.
E-mail address: aleksandar.valjarevic@tdtu.edu.vn (A. Valjarević).

https://doi.org/10.1016/j.chemosphere.2019.125171
0045-6535/