

RADON IN NIŠKA BANJA SPA WATERS

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Abstract: The most numerous investigations of radon concentration in waters in Serbia were conducted in Niška Banja spa. Niška Banja spa is considered an area with high natural radioactivity. The appearance of radon in water is due to the leaching of soil in which ²²⁶Ra nuclei decompose. The passage of groundwater through radium-rich rocks results in the collection of radium decay products, including radon ²²²Rn. This paper presents the results of several studies which measured radon concentrations in the waters of Niška Banja spa. There are three thermal springs in Niška Banja spa: „Glavno vrelo“, „Suva banja“ and „Školska česma“. The radon concentration in the waters of Niška Banja spa was found to be generally about $0.4\text{-}570\cdot 10^3$ Bq/m³. According to the available data in the literature, the highest measured radon concentration in the waters of Niška Banja spa is $1463.4\cdot 10^3$ Bq/m³.

Keywords: radon, Niška Banja spa, thermal water.

1. INTRODUCTION

There are many radon spas in Europe, most of them in Germany, Austria, Hungary, Romania, Slovenia, etc. [1]. The south-eastern part of Serbia represents an area with many well-known thermal water sources [2].

Famous radon spas in Serbia are Niška Banja spa, Sokobanja spa and Banja Badanja spa. The radon concentration in the waters of Niška Banja spa is about $0.4\text{-}570\cdot 10^3$ Bq/m³, Sokobanja spa $370\cdot 10^3$ Bq/m³ and Banja Badanja Spa $188.7\cdot 10^3$ Bq/m³. The most explored spa with regard to the activity concentration of radon in Serbia is Niška Banja spa. Niška Banja has been identified as a high natural radiation area. Niška Banja has elevated levels of radon. The reason for the increased radon concentration in Niška Banja is geological and hydrogeological characteristics of the area in which it is located [1–3].

If the water has a high level of ²²²Rn concentration, there is often an elevated radon level in the surrounding air as radon can be easily transferred from water to air [2].

Niška Banja is located 10 km south-east of Niš, near the mouth of the Nišava River into the

Southern Morava River. Mountain Koritnik rises above Niška Banja, far West branch of Suva Planina mountain. A mid-part spa is built on a 250 m altitude travertine stone terrace. The climate in Niška Banja is moderate-continental. Niška Banja was renown in the Roman times by its medicinal hot springs [4]. In Niška Banja since 1909, the karst „Glavno vrelo“ spring has been renown for its radon content and Marko Leko was the first to detect its radioactivity [5–6].

2. ORIGIN OF RADON

The presence of radon in water is due to the leaching of soil in which ²²⁶Ra nuclei decompose. On its way through radium-rich rocks groundwater collects radium decay products, including radon ²²²Rn. After eruption of groundwater to the surface, there is a sharp decrease in the concentration of radon in the water due to its contact with the surrounding air, whereby radon can easily "escape" from the water. It is not good to use this radon-rich water for drinking, which is common in some populated areas. It is very important to check the concentration of radon in water at springs and public faucets to determine the safety of drinking water [1].

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^{222}Rn is a radioisotope of radon. In nature it is found in the form of inert gas and is present in water, soil, basements and walls of buildings, as well as in building materials. The half-life of radon ^{222}Rn is $T_{1/2} = 3.82$ days, and the average life span is 5.51 days [1,3].

Radioactive noble gas radon is produced by the decay of radium isotopes in both uranium and thorium radioactive decay series. Radon decays to a number of short-lived progeny (^{218}Po , ^{214}Pb , ^{214}Bi , ^{214}Po) that are radioactive by themselves. It is soluble in water, and its origin in water is the radium from the water surrounding soil and bedrock. More precisely, radon can be found in water as a consequence of the decay of radium present in surrounding rocks and soil [2,3].

Radon is a gas without color, smell or taste. Radon is an inert gas, volatile and chemically non-reactive. It is the heaviest noble gas in the periodic table of elements. Since it is denser than air, it is usually retained at low altitudes, in rooms with poor ventilation and in basements [1,3]. Radon is the largest source of ionizing radiation in nature [1].

Radon has 37 known isotopes so far. Isotopes of this radionuclide are formed during the decay of isotopes of radium from the uranium, thorium and actinium series [1].

Although there are more radon isotopes, it is common to refer to the name "radon" as the radioisotope ^{222}Rn [1].

Radon ^{222}Rn is formed by the radioactive decay of radium ^{226}Ra , the progeny of uranium ^{238}U [3].

Water analyzes in Serbia indicate high levels of ^{222}Rn , but not high concentrations of ^{226}Ra and ^{238}U . One of the reasons for these results is that ^{226}Ra and ^{238}U are much less soluble in groundwater than ^{222}Rn [1].

^{222}Rn in groundwater is a significant indicator of its origin from the hydrogeological point of view, since waters with high concentrations of ^{222}Rn generally have high mineralization as well as increased CO_2 concentration relative to the groundwater in the environment [1].

The concentration of radon in natural waters is different. In normal, drinking and river waters it is around $3.7 \cdot 10^3 \text{ Bq/m}^3$, in sea water $1.1 \cdot 10^3 \text{ Bq/m}^3$, for lakes and rivers $0.37 \cdot 10^3 \text{ Bq/m}^3$ and for underground waters from $3.7 \cdot 10^3 \text{ Bq/m}^3$ up to $370 \cdot 10^3 \text{ Bq/m}^3$. The lower limit of radon concentration in radon waters is $180\text{-}380 \cdot 10^3 \text{ Bq/m}^3$, and in waters with high radon concentration it is above $4500 \cdot 10^3 \text{ Bq/m}^3$ [3].

According to the US Environmental

Protection Agency regulation the upper limit for ^{222}Rn in drinking water is $11 \cdot 10^3 \text{ Bq/m}^3$. According to the European Commission decision from 2001, radon level less than $100 \cdot 10^3 \text{ Bq/m}^3$ is acceptable and there is no need for any interventions for the activity concentrations that are below this limit [2,3].

3. PRESENCE OF RADON IN NIŠKA BANJA SPA WATERS

Niška Banja is located between two geotectonic units: Serbo-Macedonian massif and Carpatho-Balkanides, which results in its complex geology and tectonics. Lithologically, the spa is located within the Neogene basin whose thickness is ~500 m. Mesozoic limestone, dolomites, dolomite limestone and clastic-carbonate sediments are found beneath these sediments. Thermal springs in Niška Banja spa have low-mineralized $\text{HCO}_3\text{-Ca}$ water [2].

Niška Banja is a natural geological rarity with a large number of thermal mineral water springs. Niška Banja is an area of undisturbed environment, and the radiation detected in it is usually assumed to be at the zero level from which other contributions to the radiation of the population are then calculated [7]. It is assumed that thermal water from the springs in Niška Banja originates from mixing usual atmospheric water, which comes from the springs of Suva planina and Koritnik, and deep warm water [8]. The waters of Niška Banja belong to the natural, radioactive spa. All waters have a similar chemical composition, are characterized by small dry residues and exhibit the characteristics of karst springs [5]. There are three radioactive springs in Niška Banja: „Glavno vrelo”, „Suva banja” and „Školska česma” [7].

„Glavno vrelo” waters are used to supply spa bath and „Suva banja” waters are used to supply „Hladno kupatilo” [5].

Waters of the „Suva banja” spring are used for the supply of the open summer pool 5 and the remaining waters go through pipelines to the spring capturing of „Glavno vrelo”, where the two waters mix. From there, through pipelines, the waters go to „Niška Banja” Institute which has three stationeries („Radon”, „Zelengora” and „Terme”), „Staro kupatilo” with two pools and they also supply the „Ozren” hotel [11].

There is also a spring called „Školska česma”. In addition, there is a considerable number of smaller radioactive springs. Immediate spa terrain is particularly distinguished by the abundance of the underground radioactive waters [5].



Figure 1. „Glavno vrelo“ of Niška Banja [9]



Figure 2. „Suva banja“ spring [10]

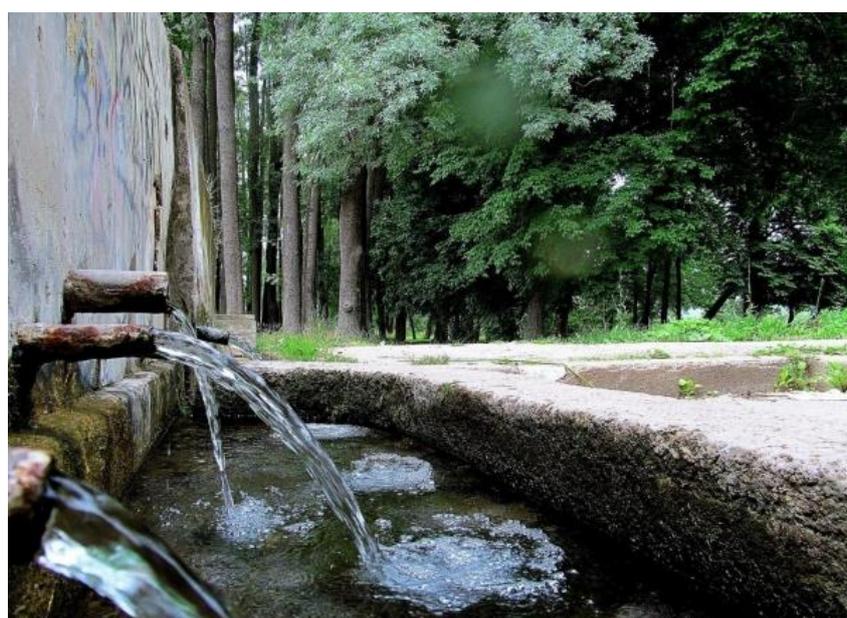


Figure 3. „Školska česma“ spring in Niška Banja [1]

The waters of Niška Banja have a very low content of ^{226}Ra (less than $1 \cdot 10^3 \text{ Bq/m}^3$), and a much higher activity of ^{222}Rn [6].

During various investigations, radon concentrations were measured in Niška Banja waters.

According to the results of D. K. Jovanovic measurements from 1938 [5], radioactivity of the „Glavno vrelo” waters varied between $141.8 \cdot 10^3 \text{ Bq/m}^3$ and $180.8 \cdot 10^3 \text{ Bq/m}^3$. The minimum radioactivity of the „Suva banja” spring was $3.8 \cdot 10^3 \text{ Bq/m}^3$, and the maximum radioactivity was $80.7 \cdot 10^3 \text{ Bq/m}^3$. The radioactivity of the „Školska česma” spring waters was $491.4 \cdot 10^3 \text{ Bq/m}^3$ and $738.5 \cdot 10^3 \text{ Bq/m}^3$. The results of radioactivity measurements of the Niška Banja springs are: for „Glavno vrelo” $143.3 \cdot 10^3 \text{ Bq/m}^3$ and for „Školska česma” $624.8 \cdot 10^3 \text{ Bq/m}^3$. In this study, measurements were made of all other springs and most of the wells, pumps and other waters in Niška Banja and its surroundings, on the basis of which the following general observations were made:

- The radioactivity of these waters ranged from 0 to $925 \cdot 10^3 \text{ Bq/m}^3$.

- The most radioactive waters are from wells near „Glavno vrelo” spring. Springs adjacent to „Glavno vrelo” spring had radioactivity that ranged

from about $148 \cdot 10^3 \text{ Bq/m}^3$ on the upper part of the spring and about $222.2 \cdot 10^3 \text{ Bq/m}^3$ at the lower part.

- Groundwater in the meadow below „Školska česma” spring is significantly radioactive. Its radioactivity reached $740 \cdot 10^3 \text{ Bq/m}^3$.

- The groundwater level of these waters is very shallow and was only 0.5-1.2 m below the surface of the terrain. Tests conducted by grounding the pump on this site show that the most radioactive waters were the waters closest to the surface. The radioactivity of these waters decreases with depth [5].

Radioactivity was found in almost all waters investigated in this study, whether underground or from springs, located in the deepwater terrain sector and downstream [5].

The highest radon concentration measured in this study in Niška Banja waters was $1463.4 \cdot 10^3 \text{ Bq/m}^3$ [5].

Paper [6] claims that the specific activity of the ^{222}Rn isotope at the moment of sampling from "Glavno vrelo" spring is $(177 \pm 4) \cdot 10^3 \text{ Bq/m}^3$, and that the specific activity of the ^{222}Rn for "Školska česma" spring is $(546 \pm 9) \cdot 10^3 \text{ Bq/m}^3$.

In the paper [11], the results of the measurements of activity concentrations of ^{222}Rn in thermal waters (water samples) of Niška Banja are presented and are shown in Table 1.

Table 1. Activity concentrations of ^{222}Rn in thermal waters (water samples) of Niška Banja [11]

Location	Activity concentration of ^{222}Rn in water samples, A [$\cdot 10^3 \text{ Bq/m}^3$]
Pool "Radon"	24.5 ± 2.4
Pool "Zelengora"	28 ± 5
Pool "number 5"	34 ± 3
"Glavno vrelo"	61 ± 5
"Školska česma"	648 ± 38

This means that all the analyzed water springs should not be used for drinking purposes [2].

From the obtained results, it can be concluded that just one water sample from public fountain „Školska česma” in Niška Banja has a really high activity concentration of ^{222}Rn , more than six times higher than the European Commission recommendations from 2001, in which a radon level less than $100 \cdot 10^3 \text{ Bq/m}^3$ is acceptable [2,3,11].

4. CONCLUSION

Niška Banja is located 10 km south-east of the town of Niš. Niška Banja is a natural geological

rarity and is characterized by a large number of thermal mineral water springs. Niška Banja is located between two geotectonic units: Serbo-Macedonian massif and Carpatho-Balkanides, which results in its complex geology and tectonics. Thermal waters from the springs in Niška Banja originate from mixing usual atmospheric water, which comes from the springs of Suva planina and Koritnik, and deep warm water. Niška Banja is an area with high natural radioactivity. The waters of Niška Banja belong to the natural, radioactive spa.

There are three thermal water springs in Niška Banja: „Glavno vrelo”, „Suva banja” and „Školska česma”.

Various values for radon concentration in

the waters of Niška Banja can be found in the literature. Based on all the above said it can be concluded that the concentration of radon in the waters of the „Glavno vrelo” spring ranges from $(61 \pm 5) \cdot 10^3$ Bq/m³ to $(177 \pm 4) \cdot 10^3$ Bq/m³. The minimum radioactivity of the „Suva banja” spring is $3.8 \cdot 10^3$ Bq/m³, and the maximum is $80.7 \cdot 10^3$ Bq/m³. Radon concentration values in the waters of the „Školska česma” spring range from $(546 \pm 9) \cdot 10^3$ Bq/m³ to $(648 \pm 38) \cdot 10^3$ Bq/m³.

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РАДОН У ВОДАМА НИШКЕ БАЊЕ

Сажетак: Најбројнија испитивања концентрације радона у водама у Србији вршена су у Нишкој Бањи. Нишка бања се сматра облашћу са високом природном радиоактивношћу. Појава радона у води последица је испирања земљишта у којем се распадају језгра ²²⁶Ra. Проласком подземне воде кроз стене богате радијумом долази до сакупљања продуката распада радијума, а међу њима и радона ²²²Rn. У овом раду приказани су резултати неколико истраживања у којима су мерене концентрације радона у водама Нишке Бање. У Нишкој Бањи постоје три термална извора: „Главно vrelo“, „Сува бања“ и „Школска чесма“. Утврђено је да је концентрација радона у водама Нишке Бање углавном око $0,4\text{--}570 \cdot 10^3$ Bq/m³. Према подацима који се могу наћи у литератури, највећа измерена концентрација радона у водама Нишке Бање износи $1463,433 \cdot 10^3$ Bq/m³.

Кључне речи: радон, Нишка бања, термална вода.

