

# Determination of <sup>226</sup>Ra and <sup>222</sup>Rn content in thermomineral water and assessment of radiation risk

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## Introduction

Determination of <sup>226</sup>Ra and <sup>222</sup>Rn activity concentration in water has been recognized as one of the most important tasks in the preservation of public health, since increased content of these radionuclides in drinking water may lead to increased health risk. Generally, the presence of <sup>226</sup>Ra in water samples is potentially dangerous due to its radiotoxicity and has been related to the cancer of bones<sup>1</sup>. On the other hand, its decay product <sup>222</sup>Rn is recognized as a potential cause for the development of lung cancer. The concentration of <sup>226</sup>Ra in water depends mostly on the geology of the area and may be elevated if water passes through rocks with elevated content of <sup>238</sup>U. Thus, it is especially important to measure the content of <sup>226</sup>Ra and <sup>222</sup>Rn in thermal and mineral water, since these waters are groundwater and a high concentration of <sup>226</sup>Ra is expected to be found<sup>2</sup>. At the same time, thermal and mineral water is used for different kinds of treatment<sup>3</sup>, such as musculoskeletal diseases, arterial hypertension, bone fracture, post-traumatic conditions, neurological disorders, sports injury, etc, which may lead to increased doses due to inhalation and ingestion.

## Materials and Methods

The samples were collected from **3 locations from spa Niška Banja**<sup>4</sup> (southern part of Serbia)–Školska česma (Samples No. 1–4), Glavno Vrelo (Sample 5) and Suva banja (Sample 6). Public fountain Školska česma has 4 pipes, thus 4 samples were collected from this location. The protocol for measurement with **RAD7** was selected to be WAT250.

For the determination of radon activity concentration by **LSC** method, it was necessary to prepare samples in the following way: 10 ml of sample was mixed with 10 ml of Mineral Oil scintillation cocktail. After performed measurements, the prepared samples were left in dark place for more than 30 days, in order to achieve secular radioactive equilibrium between <sup>226</sup>Ra and its decay progenies.

Furthermore, the samples were mixed with Ultima Gold AB cocktail with an aim of measuring the **gross alpha and beta activity** concentration.

The **annual effective doses** from ingestion of <sup>222</sup>Rn and <sup>226</sup>Ra where estimated for adults, assuming direct consummation of 2 l per day:

$$E_{222Rn} [mSv] = 10^{-8} \left[ \frac{Sv}{Bq} \right] \cdot A(^{222}Rn) \left[ \frac{Bq}{l} \right] \cdot 730 [l] \cdot 10^3 \left[ \frac{mSv}{Sv} \right]$$
$$E_{226Ra} [mSv] = 0.28 \left[ \frac{\mu Sv}{Bq} \right] \cdot A(^{226}Ra) \left[ \frac{Bq}{l} \right] \cdot 730 [l] \cdot 10^{-3} \left[ \frac{mSv}{\mu Sv} \right]$$

## Results and Discussion

Table 1 <sup>222</sup>Rn activity concentrations measured with active radon device RAD7 and with LSC method using Quantulus 1220. Date of measurement was 29.4.2022 (10 days after preparation).

Sample No.	A <sub>RAD7</sub> [Bq l <sup>-1</sup> ]	A <sub>LSC</sub> [Bq l <sup>-1</sup> ]
1	420±25	620±13
2	415±25	510±12
3	474±27	540±12
4	422±21	525±12
5	111±11	160±7
6	14±4	48±4

Table 2 <sup>226</sup>Ra activity concentrations measured with LSC method using Quantulus 1220 (two phased cocktail Mineral Oil).

Sample No.	A [Bq l <sup>-1</sup> ] after 44 days	A [Bq l <sup>-1</sup> ] after 83 days
1	<0.09	<0.09
2	<0.09	<0.09
3	<0.09	<0.09
4	<0.09	<0.09
5	0.174±0.009	0.109±0.005
6	<0.09	<0.09

Table 3 Gross α/β activity concentration in samples measured 10 and 83 days after sample preparation.

Sample No.	Measured on date 29.4.2022.		Measured on date 12.7.2022.	
	Gross α [Bq l <sup>-1</sup> ]	Gross β [Bq l <sup>-1</sup> ]	Gross α [Bq l <sup>-1</sup> ]	Gross β [Bq l <sup>-1</sup> ]
1	12.6±1.8	3.2±0.5	0.039±0.005	<0.04
2	12.5±1.8	3.1±0.5	0.029±0.004	<0.04
3	9.7±1.4	2.4±0.3	0.029±0.004	<0.04
4	11.6±1.6	2.9±0.4	0.024±0.003	<0.04
5	3.8±0.5	0.86±0.12	0.148±0.021	<0.04
6	1.06±0.15	0.137±0.020	0.101±0.014	<0.04

Table 5 The annual effective doses from ingestion of <sup>222</sup>Rn and <sup>226</sup>Ra.

Sample No.	E ( <sup>222</sup> Rn) [mSv]	E ( <sup>226</sup> Ra) [mSv]
1	4.5	0.018
2	3.7	0.018
3	3.9	0.018
4	3.8	0.018
5	1.2	0.04
6	0.4	0.018

Table 4 Results of gamma spectrometry analysis

Sample No.	A [mBq/l]			
	<sup>137</sup> Cs	<sup>226</sup> Ra (mean)	<sup>226</sup> Ra (186 keV)	<sup>232</sup> Th
1–4	< 1.7	3.3±1.1	88±18	2.7±0.3
5	< 1.2	21±3	770±50	1.79±0.24
6	< 2.6	9.0±1.5	14±3	0.51±0.10

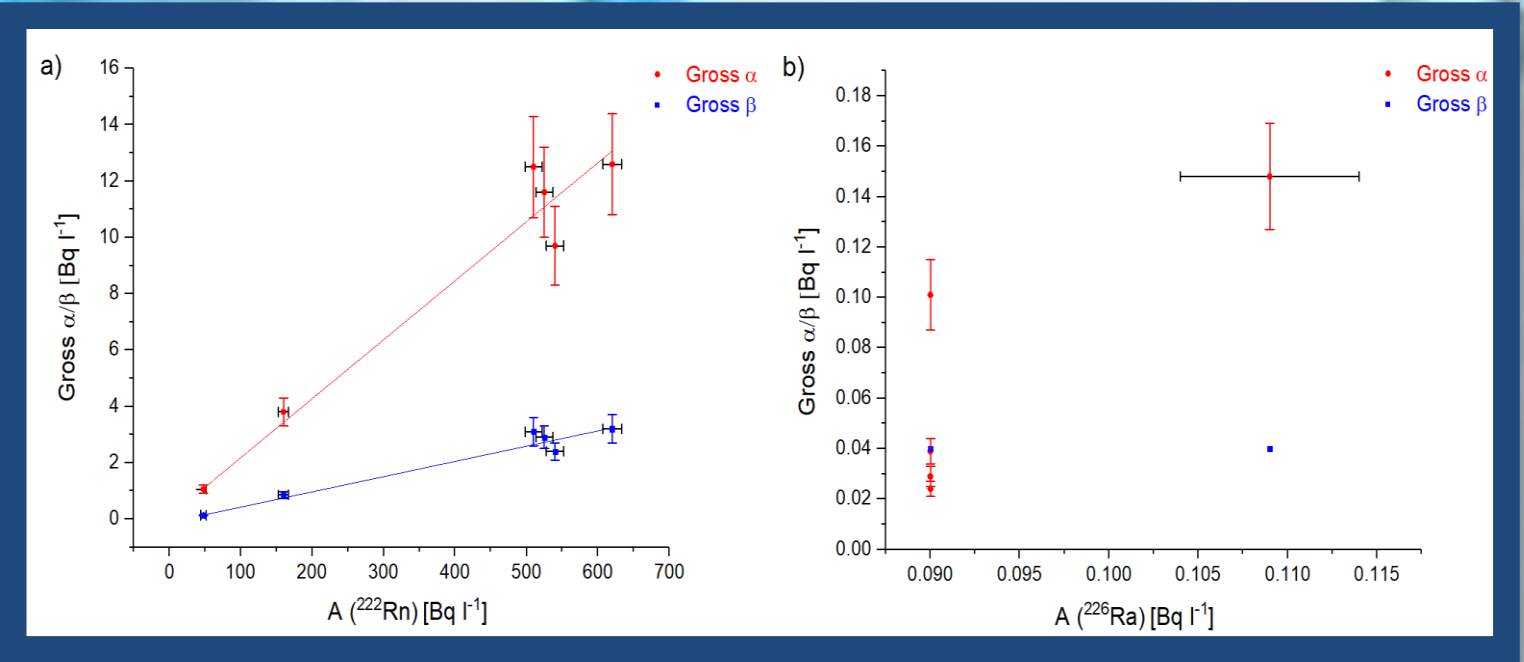


Figure 1 Correlation between gross alpha and beta activity concentration with activity concentration of <sup>222</sup>Rn (a) and <sup>226</sup>Ra (b).

## Conclusions

- LCS method showed higher values in comparison with RAD7 results, and possible reasons are fact that used cocktail, to some extent, prevent radon diffusion from the sample and fact that samples for LSC were taken first from the glass sampling bottle, thus some losses of radon occurred
- In case of measuring radium in the samples, 44 and 83 days after preparation, the absence of radon and its progenies was noticed, thus it can be concluded that this cocktail has not prevent diffusion of radon in long terms
- Correlation with GAB activity concentration showed that in the first set of measurement radon concentration is highly correlated with high values of gross GAB
- Gamma spectrometry measurements also showed interesting results: the activity concentration of <sup>226</sup>Ra is significantly higher when it is calculated based on direct gamma line of <sup>226</sup>Ra than based on gamma lines of its progenies, except in case of sample 6, where secular radioactive equilibrium has been established
- According to regulation of Republic of Serbia, waters from sites 5 and 6 could not be used for drinking. Also, radon activity concentrations in all 3 samples are above 100 Bq/l
- Annual effective dose due to ingestion of <sup>226</sup>Ra are found to be negligible, in contrary to the dose from ingestion of <sup>222</sup>Rn, which was found to be 0.4–4 mSv, which is above 0.1 mSv (considered as an individual dose criterion of 0.1 mSv for the annual consumption of drinking water, regardless of the origin of radionuclide, according to WHO).

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