Prevalence of radon and metals in natural springs in the Sokobanja area

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Abstract: In this study, radon concentrations in natural springs were measured at 9 locations in the area of Sokobanja, using a RAD-7 radon monitoring system (DURRIDGE Co., USA). The average value of radon concentration was 19.6 Bq/l. Annual effective doses due to ingestion and inhalation of radon in water were calculated. Concentrations of metals were measured using the ICP OES technique by EPA 200.7:1994 method and their mean values were: Ca - 80.8 mg/l, Na - 8.7 mg/l, Mg - 8.6 mg/l, K - 1.8 mg/l and Pb - 0.002 mg/l. Based on the results obtained in the study and the reference levels recommended for the parameters under consideration, water from Sokobanja natural sources can be considered safe for drinking.

Keywords: water, radon, heavy metals, health risk, Sokobanja

1. Introduction

Radioactive gas radon is a direct product of the decay of radium, characterized by its high solubility in water. According to the decision of the World Health Organization, the reference level of radon in drinking water is 100 Bq/l [1], while the reference level of radon in drinking water set by the United States Environmental Protection Agency is 11.1 Bq/l [2]. Heavy metals exist in the environment naturally as trace elements in rocks and soils and also in natural waters. When taken into the organism, they adhere to

enzymes, inhibiting their function, where they can cause numerous physiological and neurological consequences [3].

This paper presents the results of testing the presence of radon and metals in natural mineral spring waters at 9 locations in the Sokobanja area, in order to assess whether their levels can have a negative impact on public health.

2. Material and methods

Sampling waters. Water was sampled in two bottles from each site, one for radon detection and the other for heavy metals detection. The bottles were closed and the exact time, date and place of sampling were marked following the recommendation rules from the Policy book of the Republic of Serbia [4].

Detection of radon. Detection of radon was conducted at the Laboratory for Testing Radioactivity of Samples and Doses of Ionizing and Non-Ionizing Radiation, at the Faculty of Sciences, University of Novi Sad. Radon concentration in mineral water samples was determined using the RAD H2O system (Durrige Co.) [5].

Detection of metals. Analysis of metals in water samples was carried out in the laboratory for testing the quality and healthiness of foodstuffs and items of general use „Institute Topčider", Jugoinspekt Beograd ad. Concentrations of metals were measured using ICP OES technique by EPA 200.7:1994 method [6].

3. Results and discussion

Table 1 presents the summarized values of the investigated parameters in this area, as well as their maximum allowed values.

Table 1. Summarized results of this research in the Sokobanja area.

	C_{Rn} (Bq/l)	Ca (mg/l)	K (mg/l)	Mg (mg/l)	Na (mg/l)	Pb (mg/l)
Max	111	92.0	5.8	14.0	25.1	0.005
Average value	19.6	80.8	1.8	8.6	8.7	0.002
Min	1.2	75.3	0.5	1.8	1.3	0.001
Refer. levels	100	Max 200	Max 12	Max 50	Max 200	Max 0.01

Metals. Based on the summarized results, the mean values of measured elements are as follows: for calcium - 80.8 mg/l, for potassium - 1.8 mg/l, for magnesium - 8.6 mg/l, for sodium - 8.7 mg/l and for lead - 0.002 mg/l. The values of analyzed contents of metals were far below in terms of values given by the EU Directive [7] and related to the Policy about the quality and other requests for natural, mineral, and table water [4].

Radon. The mean value of radon concentration in water from 9 selected locations is 19.6±4.5 Bq/l, which is below the recommended value of 100 Bq/l. The recommended value of 100 Bq/l was slightly exceeded in only one sample. However, EU Council Directive [8] establishes parametric values between 100 and 1000 Bq l^{-1} in the EU

countries. Therefore, it can be considered that the water from Sokobanja natural sources is radiologically safe and can be used for drinking.

Doses from radon. Annual effective doses due to ingestion and inhalation of radon in water were calculated using the following two equations, respectively [9, 10]:

$$AED_{ing} = C_{Rn} \times A_i \times D_{f(ing)} \quad (1)$$

$$AED_{inh} = C_{Rn} \times R \times T \times F \times D_{f(inh)} \quad (2)$$

where C_{Rn} is radon activity concentration in water; $D_{f(ing)}$ and $D_{f(inh)}$ are dose conversion factors for radon ingestion and radon inhalation, respectively; A_i is the annual water intake; T is indoor occupancy time, R is the ratio of radon in air to radon in water, F is the equilibrium factor between radon and its progeny.

The results of radon dose calculation are presented in Table 2. Average annual effective doses from radon ingestion were estimated to be in the range of 6 – 590 μSv/y for infants, 2 –216 μSv/y for children, and 3 – 284 μSv/y for adults. Annual effective doses from radon inhalation ranged between 3 and 280 μSv/y.

Table 2. Annual effective doses from radon ingestion and inhalation.

Sample	AED_{ing} [μSv/y]			AED_{inh} [μSv/y]
	Infants	Children	Adults	
1	590	216	284	280
2	93	34	45	44
3	6	2	3	3
4	37	14	18	18
5	17	6	8	8
6	47	17	22	22
7	74	27	36	35
8	16	6	8	8
9	54	20	26	26

4. Conclusions

The mean value of radon concentration in water from 9 selected locations is 19.6±4.5 Bq/l, which is below the recommended value of 100 Bq/l. The concentrations of heavy metals are below the recommended values and their mean values are as follows: Ca - 80.8 mg/l, K – 1.8 mg/l, Mg – 8.6 mg/l, Na – 8.7 mg/l, and Pb – 0.002 mg/l. Average annual effective doses from radon ingestion were 103.5, 38.1, and 50 μSv/y for infants, children, and adults, respectively, while the average annual effective dose from inhalation was estimated to be 49.3 μSv/y. Accordingly, water from Sokobanja natural sources is radiologically safe and can be used for drinking.

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