

## NATURAL RADIONUCLIDES IN SOME ROMANIAN MEDICINAL MINERAL WATER

Elena Botezatu, Olga Iacob, Andreea Grigorescu

Institute of Public Health, Iași, România

**Abstract. Aim.** There are many natural springs and drilled wells in the north-eastern of Romania, which produce waters enriched in minerals and are used as medicinal waters. For this reason, we were interested in finding out the extent to which these waters can be a natural radiation source. This survey aimed at assessing the radioactive content of these waters and their contribution to the population exposure. **Materials and methods.** The mineral water springs clustered in northeastern Romania and their uses for medicinal aims have been inventoried. Between 1999 and 2005, mineral water samples were collected several times over this period at locations of mineral water in the Slanic Moldova (Bacău district) and Vatra Dornei (Suceava district) spa resorts. Also, some communal springs, which are open to public and frequently used as medicinal drinking water without any sanitary certificate in the same districts, were studied. All samples (800) were analysed for gross alpha and beta radioactivity and the natural radioelements of utmost interest (natural uranium and thorium, radium-226 and potassium-40). **Results and discussion.** The natural radioactivity varies over a large range (up two orders of magnitude). The activity concentrations in water samples were found to be over the detection limit, with values ranging from 1.5 to 74 mBq/l, from 1.5 to 25 mBq/l and from 17 to 1780 mBq/l for  $^{226}\text{Ra}$ ,  $^{238}\text{U}$  and  $^{40}\text{K}$ , respectively. It can be seen a similar situation in both districts that is the low concentration of  $^{232}\text{Th}$  (0.4 - 2.5 mBq/l). The average concentrations of radium-226 were three times higher in water from Bacău district, but the uranium-238 activity was twice lower than that in Suceava district. The geometric means values for radium-226 were of 22.6 mBq/l and 5.7 mBq/l in Bacău and Suceava district, while, those for uranium-238 were 6.2 mBq/l and 9.6 mBq/l, respectively, for the same districts. The estimated effective doses received by individuals undergoing mineral water drinking cure are of 0.06 – 0.65  $\mu\text{Sv}$  and through inhalation are of 0.05 up to 0.4  $\mu\text{Sv}$ . The individual effective dose rates in external cure treatment are very small, respectively,  $(1.3 - 3.5) \times 10^{-4} \mu\text{Sv}$  by immersion and  $(0.2 - 4.4) \times 10^{-8} \mu\text{Sv}$  by washing. **Conclusions.** An hypothetical person that undergoes a cure of mineral water by ingestion, inhalation and immersion is receiving an average supplementary dose of only 0.3  $\mu\text{Sv}$  over background radiation of  $2,450 \mu\text{Sv}\cdot\text{y}^{-1}$  due to all natural radiation sources in Moldavia (northeastern of Romania). The contribution of mineral water used in therapeutic purposes to the natural irradiation of population is very slight, almost insignificant.

**Key words:** mineral water, springs, medicinal water, internal and external cure treatment, natural radioactivity, gross alpha and beta radioactivity, specific activities of natural uranium, natural thorium, radium-226, potassium-40, effective doses

**Rezumat. Scop.** Există numeroase izvoare de apă minerală în Nord-Est-ul României, care sunt utilizate în scop terapeutic ca ape medicinale. De aceea am fost interesați în ce măsură aceste ape pot constitui o sursă de iradiere naturală a populației. Scopul acestui studiu a fost de a determina conținutul radioactiv al acestor ape și contribuția lor, prin iradiere internă sau externă funcție de tipul de tratament, la expunerea populației. **Material și metodă.** Au fost inventariate sursele de apă

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minerală de pe întreg teritoriul Moldovei și modul lor de utilizare în scop medicinal. În cadrul acestei categorii de ape, în perioada 1999 – 2005, s-au analizat probe de ape minerale provenind din stațiunile Slănic Moldova (județul Bacău), Vatra Dornei (județul Suceava) precum și izvoare utilizate de localnici pentru diverse tratamente, fără avizare medicală. După determinarea radioactivității alfa și beta globale, toate probele (800) au fost analizate din punct de vedere al conținutului de  $^{226}\text{Ra}$ , uraniu natural (respectiv uraniu-238), toriu natural (respectiv toriu-232) și potasiu-40. **Rezultate și discuții.** Radioactivitatea naturală a variat într-un domeniu larg de valori, până la două ordine de mărime. Concentrațiile de activitate în probele de apă au variat de la 1,5 până la 74 mBq/l pentru  $^{226}\text{Ra}$ , de la 1,5 până la 25 mBq/l pentru  $^{238}\text{U}$  și de la 17 până la 1780 mBq/l pentru  $^{40}\text{K}$ . În ambele județe s-au înregistrat valori mici pentru concentrațiile de activitate ale  $^{232}\text{Th}$  (0,4 – 2,5 mBq/l). În apele din județul Bacău, concentrațiile medii de radium-226 au fost de 3 ori mai mari, dar concentrațiile de uraniu-238 au fost de 2 ori mai mici decât cele din apele din județul Suceava. Valorile mediilor geometrice pentru radium-226 au fost de 22,6 mBq/l și 5,7 mBq/l respectiv în județele Bacău și Suceava, în timp ce valorile pentru uraniu-238 au fost de 6,2 mBq/l și 9,6 mBq/l, respectiv, pentru aceleași județe. În cadrul unei cure cu ape minerale o persoană primește prin ingestie o doză efectivă de 0,06 – 0,65  $\mu\text{Sv}$  iar prin inhalare o doză de 0,05 până la 0,4  $\mu\text{Sv}$ . Dozele efective datorate unui tratament extern cu ape minerale sunt foarte mici, respectiv de  $(1,3 - 3,5) \times 10^{-4} \mu\text{Sv}$  prin imersie și de  $(0,2 - 4,4) \times 10^{-8} \mu\text{Sv}$  prin spălare. **Concluzii.** O persoană ipotetică din populație care urmează o cură de tratament cu apă minerală prin ingestie, inhalare și/sau imersie primește o doză suplimentară de numai 0,3  $\mu\text{Sv}$  față de fondul natural de iradiere de 2450  $\mu\text{Sv}/\text{an}$  din toate sursele naturale de iradiere pentru Moldova (Nord-Estul României). Contribuția apei minerale, utilizate în scopuri terapeutice, la iradierea naturală a populației este foarte mică, aproape nesemnificativă.

**Cuvinte cheie:** apă minerală, izvoare, apă medicinală, tratament prin cură internă și/sau externă, radioactivitate naturală, radioactivitate alfa și beta globală, activitate specifică a uraniului și toriului natural,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$ , doze efective

### INTRODUCTION

As a rule, mineral water springs run across highly mineralized rocks. The geological sources of natural mineral water are known as aquifers, which may be of different types, and they vary greatly in terms of their depth, horizontal extent, composition, and permeability. While passing through the underground strata, water picks up minerals and other elements depending on the chemical make-up of the strata. That is why they have higher concentrations of minerals, trace minerals and natural radioelements than other kinds of water. Most of the radionuclides are minerals dissolved in water. Radioactive minerals occur

irregularly in the bedrock, similar to other minerals and they dissolve easily in water. Bedrock contains naturally occurring radioactivity including uranium, thorium, radium and potassium. The natural radioactivity results from water passing through deposits of naturally occurring radioactive materials.

There are many natural springs and drilled wells in the north-eastern part of Romania, which produce waters enriched in minerals. The mineral water sources over the entire surface of Moldova county, as well as their uses have been inventoried.

Many mineral water springs are traditionally used as drinking mineral

water sources in the area. During the period from 1997 to 2000, we accomplished a study that had as basic objectives the radioactivity control of the drinking mineral waters according to existing standards and evaluation of doses to population by ingestion of mineral water (bottled waters commercially available for human intake and some spring waters).

Other mineral water springs are suitable for curing various disorders or diseases. The chemical composition and radioactivity of these waters have got very favorable physiological effects, being reputed for their therapeutic and medicinal value. These mineral waters are widely used for the treatment of gastrointestinal and biliary disorders, urinary tract infections and lithiasis, chronic obstructive pulmonary disease and acute bronchitis, cardiovascular and peripheral vascular disorders, rheumatic diseases, ophthalmologic disorders and gingivitis. For this reason, we were interested in finding out the extent to which these waters can be a natural radiation source.

This survey aimed at assessing the radioactive content of these waters and their contribution to the population exposure.

#### MATERIAL AND METHODS

Between 1999 and 2005, mineral water samples were collected several times over this period at various locations of mineral water in two representative spas, one in Slanic Moldova (Bacău district) and another one in Vatra Dornei (Suceava district). Some communal springs, which are open to public and frequently used as medicinal drinking

water, without any sanitary certificate in the same districts, have been studied, as well. The mineral water samples were directly obtained at the source, both in the cold and hot seasons, and analyzed without any addition or previous treatment.

The sampling and analysis of samples were carried out using Romanian standardized methods (1). In all samples, total alpha and beta radioactivity and the natural radioelements of utmost interest (natural uranium and thorium, radium-226 and potassium-40) have been measured. The water samples were concentrated by evaporation. The gross alpha particle activities of water sample were measured using a ZnS (Ag) detector system and a plastic scintillation system for the gross beta activities. Efficient techniques of element specific separation were developed, allowing the analysis of each element. Uranium-238 and thorium-232 levels were calculated after determining the contents of natural uranium and thorium using a method based on their separation and purification on a strong basic anion exchange resin and spectrophotometric measurement in terms of the Arsenazo III complex. Radium-226 was determined through its decay product radon-222, and by alpha-ray measurement in a scintillation chamber. Levels of potassium-40 were determined by calculation following photometric dosing in the flame emission mixture of natural potassium isotopes. Total dissolved solids (TDS) were usually measured as the residues when a liter of water is evaporated at 180<sup>0</sup> C. The TDS were

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determined in all samples by evaporation to dryness and weighing the residue.

Based on the mean concentrations values of natural radionuclides in the mineral water and using the cure model (ingestion, inhalation, bathing), the effective doses were estimated. The individual doses have been calculated taking into account the content of natural radioelements, the exposure way as well as the dose conversion coefficients specific to each procedure and radioelement (2 - 7).

### RESULTS AND DISCUSSION

The water aquifers vary in their depth ranging from less 10m to more than 150 m below the earth's surface. The total dissolved solids (TDS) content of mineral water ranged from 0.5 g/L to 31 g/L, about 35% of the waters being slightly mineralized. The carbonated samples tended to show higher TDS values.

Pearl of Moldavia, spa of Slanic-Moldova is known for its springs of carbonated, bicarbonated, slightly sulphurous, having CO<sub>2</sub> and H<sub>2</sub>S in various proportions, chlorided, iodided, sodic, hypertonic, hypotonic and certain oligomineral waters. The Slanic Moldova waters are subdivided in two aquifer systems, varying in depth from 80 to 150 meters. The flow of all the springs in the area varies extensively, under the influence of rainfall and water level of Slanic stream. The therapeutic qualities of the mineral waters make them suitable for the treatment of digestive disorders, hepatobiliary diseases, metabolic and nutrition diseases, kidney and urinary diseases. There are fountains for internal cures with mineral water and

facilities for respiratory therapy (aerosols and inhalations). These mineral waters are used for internal treatment by ingestion of 200 - 800 ml/day in all cures, excepting diuresis cures when 1.5 - 2 L/day are used.

The Vatra Dornei mineral waters catching are achieved at depth varying from 8 to 80 m (clayey and sandy matrix). The springs of carbonated, ferruginous (13-20 mg Fe<sup>3+</sup>/L), slightly bicarbonated, sodic, calcic, magnesian, hypotonic mineral waters are used mainly for the treatment of cardiovascular diseases but also in the cures for the treatment of rheumatic diseases, post-traumatic conditions, peripheral and central neurological diseases, endocrine disorders, gynecological, respiratory, neurotic, metabolic and nutrition, digestive and other disorders. There are special fountains for internal cures of mineral water and artificial mofette. In external cures, these mineral waters are effectual in the treatment for degenerative and abarticular rheumatic diseases, cardiovascular, gynecological and other diseases. The external cure consists in immersing the patients in bath tubs filled with 250 liters of warm mineral water.

The mineral waters used by the local inhabitants, without medical recommendation, are sulphur waters, in general slightly carbonated, their spring being located at 6 - 24 m depth. The mean specific values of the mineral waters used for medical purposes in the spas as well as the waters used by the local population are presented in tables 1 and 2.

The natural radioactivity varies over a large range (up two orders of magnitude).

The radioactivity level of this water is comparable to the radioactivity grade of the bottled drinking mineral water in the same districts (8). The data obtained by our study are significantly below that those reported by other studies (9 - 15). The activity concentrations in water samples were found to be over the detection limit, with values ranging from 1.5 to 74 mBq/L, from 1.5 to 25 mBq/L and from 17 to 1780 mBq/L for  $^{226}\text{Ra}$ ,  $^{238}\text{U}$  and  $^{40}\text{K}$ , respectively. There can be seen a similar situation in both

districts, i.e. the low concentration of  $^{232}\text{Th}$  (0.4 - 2.5 mBq/L). In most cases, the activity concentrations of radium-226 were three times higher in water from Bacău district, but the uranium-238 activity concentrations were 2 times less than that in Suceava district. The geometric means values for radium-226 were of 22.6 mBq/L and 5.7 mBq/L in Bacău and Suceava district, while, those for uranium-238 for the same districts, were 6.2 mBq/L and 9.6 mBq/L, respectively.

**Table 1. Natural radioactivity (m ± SD) in natural mineral waters used as medicinal waters (in mBq L<sup>-1</sup>) - Bacău district**

No	Water sample	Natural Uranium	$^{238}\text{U}$	$^{226}\text{Ra}$	$^{232}\text{Th}$	Gross alpha radioactivity	$^{40}\text{K}$	Gross beta radioactivity
<b>Slanic-Moldova</b>								
1	First Spring 1*	7.2 ± 4.1	3.5 ± 2.1	19.7 ± 5.5	0.45 ± 0.21	678 ± 140	1107 ± 209	1084 ± 702
2	Second Spring 1**	5.3 ± 1.9	2.5 ± 0.9	53.5 ± 21.2	1.09 ± 0.43	203 ± 15	1410 ± 372	772 ± 246
3	Spring 2 #	16.4 ± 12.3	8.1 ± 5.8	5.7 ± 4.5	1.51 ± 0.43	75 ± 14	170 ± 65	400 ± 60
4	Spring 3**	10.3 ± 2.9	5.0 ± 2.1	35.3 ± 12.4	0.73 ± 0.20	47 ± 22	2900 ± 910	578 ± 379
5	Spring 5 **	19.9 ± 14.3	9.6 ± 6.4	3.7 ± 5.5	1.5 ± 0.61	43 ± 10	263 ± 81	395 ± 412
6	Spring 6 *	0.4 ± 0.2	0.2 ± 0.1	34.5 ± 11.2	1.74 ± 0.45	400 ± 188	3596 ± 820	1112 ± 200
7	Spring 8 *	24.1 ± 9.4	11.6 ± 4.5	23.7 ± 12.7	0.65 ± 0.19	85 ± 8,5	1520 ± 380	900 ± 240
8	Spring 10 *	15.4 ± 6.2	7.4 ± 3.0	57.0 ± 14.2	0.51 ± 0.08	45 - 1130	2466 ± 410	1331 ± 266
9	Spring 14 *	4.0 ± 1.1	1.9 ± 0.5	122 ± 20	1.82 ± 0.61	< 20 - 744	2328 ± 303	2261 ± 452
10	Spring 15 *	21.0 ± 6.1	10.1 ± 2.9	80.2 ± 20.1	1.18 ± 0.53	872 ± 163	1875 ± 419	697 ± 300
11	Well 2 **	17.6 ± 6.1	8.5 ± 2.9	9.7 ± 6.1	0.54 ± 0.18	294 ± 48	314 ± 109	487 ± 370
12	300 steps spring *	9.1 ± 8.0	4.4 ± 3.9	3.4 ± 2.6	0.95 ± 0.28	75 ± 37	265 ± 24	347 ± 106
<b>Moinești</b>								
1	Spring 1*	11,2 ± 8.6	5.4 ± 4.1	7.4 ± 5.5	0.9 ± 0.01	56 ± 12	314 ± 110	105 ± 25
2	Spring 2*	19.3 ± 3.7	9.3 ± 2.0	9.1 ± 3.2	1.9 ± 0.64	120 ± 28	240 ± 73	437 ± 82
3	Spring 3*	4.9 ± 1.6	2.4 ± 0.9	6.3 ± 2.8	0.6 ± 0.05	71 ± 21	310 ± 82	591 ± 109

\* Ingestion

\*\* Ingestion and inhalation

# Washing of eyes

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**Table 2. Natural radioactivity (m ± SD) in natural mineral waters used as medicinal waters (in mBq L<sup>-1</sup>) - Suceava district**

No	Water sample	Natural Uranium	<sup>238</sup> U	<sup>226</sup> Ra	<sup>232</sup> Th	Gross alpha radio-activity	<sup>40</sup> K	Gross beta radio-activity
<b>Vatra Dornei</b>								
1	Central Tank***	15.2 ± 8.6	7.4 ± 5.9	6.05 ± 5.1	0.96 ± 0.45	62 ± 24	121 ± 53	160 ± 48
2	Est Spring***	17.8 ± 16.6	8.6 ± 8.2	2.9 ± 0.2	1.01 ± 0.61	51 ± 14	152 ± 117	187 ± 77
3	Vest Spring***	20.9 ± 16.2	10.1 ± 7.6	12.9 ± 14.0	0.97 ± 0.62	106 ± 85	56,5 ± 42	1312 ± 410
4	Spa Spring***	3.9 ± 1.9	1.9 ± 0.9	6.0 ± 5.0	0.16 ± 0.17	43 ± 11	168 ± 39	210 ± 55
5	Drilling 6***	16.3 ± 13.1	7.9 ± 6.1	1.8 ± 0.7	0.79 ± 0.58	36 ± 9	195 ± 87	225 ± 43
6	Drilling P13 **	48.59 ± 19.2	23.5 ± 8.7	3.1 ± 0.7	1.16 ± 0.14	312 ± 92	260 ± 74	894 ± 143
7	Mofette**	36.8 ± 11.1	17.8 ± 6.5	1.9 ± 0.4	1.9 ± 0.6	73 ± 19	28 ± 12	91 ± 28
8	Guard Spring*	14.26 ± 7.3	6.0 ± 3.8	4.8 ± 1.7	0.57 ± 0.21	15 ± 10	51 ± 9,2	87 ± 16
9	Bizum Spring*	39.08 ± 5,71	18,9 ± 7,3	3,2 ± 2,0	3,35 ± 0,32	19 ± 10	9 ± 2	57 ± 19
<b>Iacobeni</b>								
1	Sulphur Spring 1*	32.1 ± 9.8	15.5 ± 4.3	1.1 ± 0.3	1.23 ± 0.33	20 ± 10	53 ± 33	204 ± 93
<b>Neagra Brosteni</b>								
1	Black Brosteni Spring*	19.52 ± 6.1	9.4 ± 2.9	40.4 ± 9.5	< 0.082	105 ± 28	162 ± 33	189 ± 67
<b>Lesu Ursului</b>								
1	Bear's carcass spring*	15.7 ± 4.2	7.6 ± 1.7	1.1 ± 0.4	0.14 ± 0.03	140 ± 34	31 ± 8	140 ± 29

\* Ingestion

\*\* Inhalation

\*\*\* Bath

In order to estimate the irradiation doses, we have calculated the mean arithmetic values of activity concentrations as their variability in the samples is high. As we can see from the table 3, the concentration of radium and potassium in the water used by ingestion or inhalation are higher in the Bacău district, compared to the Suceava district. The situation is reverse for the concentrations of uranium and thorium. It is interesting

to note that all the waters used for external treatment (bathing, washing), show roughly equal concentrations of radium, uranium and potassium, per pairs of districts, excepting the concentrations of thorium, which is higher in the Bacău district (table 3). Internal exposure arising from the intake of long-lived natural radionuclides through the ingestion of drink mineral water or the inhalation of aerosols in mofette was evaluated taking into

account the natural radioactive content of water and the consumption per type of cure. In the case of mineral waters used in therapeutical procedures by internal 18 days cures, we have took into calculation the maximum consumption, i.e. 800 ml/day for an ingestion cure and 40 ml/day for an

inhalation cure, respectively. In the case of mineral waters used for external therapy by bathing procedures, 250 L/day are being used.

**Table 3. Average activity concentrations ( $m \pm SD$ ) of natural radionuclides in medicinal mineral water samples (County Moldavia – Romania 1999 - 2003)**

DISTRICT	$^{226}\text{Ra}$ mBqL <sup>-1</sup>	$^{238}\text{U}$ mBqL <sup>-1</sup>	$U_{\text{nat}}$ mBqL <sup>-1</sup>	$Th_{\text{nat}}$ mBqL <sup>-1</sup>	$^{40}\text{K}$ mBqL <sup>-1</sup>	Notes
<b>Internal treatment</b>						<b>Ingestion (200-800 ml/day) 12-18 days - cure in the spa</b>
BACĂU	43.9 ± 30.4	6.3 ± 3.5	13.0 ± 7.2	0.8 ± 0.4	1431 ± 345	Slănic-Moldova Resort
BACĂU	7.4 ± 5.5	5.4 ± 4.1	11.2 ± 8.6	0.9 ± 0.01	314 ± 110	Mineral springs used by the local population
SUCEAVA	10.7 ± 9.1	12.9 ± 3.6	26.6 ± 7.5	1.2 ± 0.7	69 ± 52	Mineral springs used by the local population
<b>Internal treatment</b>						<b>Inhalation of aerosols 12-18 days - cure in the spa</b>
BACĂU	25.6 ± 23.1	6.4 ± 3.2	13.3 ± 6.7	1.0 ± 0.6	736 ± 520	Slănic-Moldova Resort
SUCEAVA	2.4 ± 0.7	21.2 ± 3.3	43.8 ± 6.7	1.5 ± 0.9	87 ± 32	Vatra-Dornei Resort
<b>External treatment</b>						<b>Immersion (250 L mineral water in bath tub) 12-18 days - cure in the spa</b>
SUCEAVA	6.1 ± 5.6	9.9 ± 6.2	20.5 ± 13.9	0.8 ± 0.5	161 ± 70	Vatra-Dornei Resort
<b>External treatment</b>						<b>Ophthalmology (washing of eyes)</b>
BACĂU	5.7 ± 4.6	8.1 ± 5.8	16.7 ± 12.4	1.5 ± 0.4	170 ± 65	Slănic-Moldova Resort

We are presenting in table 4 the individual effective doses estimated for each type of mineral water and type of cure. The estimated effective doses received by individuals undergoing mineral water drinking cure are of 0.06 – 0.65  $\mu\text{Sv}$  and through inhalation are of

0.05 up to 0.4  $\mu\text{Sv}$ . The individual effective dose rates in external cure treatment are very small, respectively,  $(1.3 - 3.5) \times 10^{-4} \mu\text{Sv}$  by immersion and  $(0.2 - 4.4) \times 10^{-8} \mu\text{Sv}$  by washing.

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**Table 4. Individual average effective doses ( $m \pm SD$ ) due to the use of mineral water for the treatment of various disorders**

DISTRICT	$^{226}\text{Ra}$	$U_{\text{nat}}$	$^{232}\text{Th}$	$^{40}\text{K}$	Total	Notes
<b>Internal treatment</b>	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	<b>Ingestion 12-18 days - cure in the spa</b>
BACĂU	$0.22 \pm 0.15$	$0.008 \pm 0.004$	$0.014 \pm 0.006$	$0.13 \pm 0.03$	$0.37 \pm 0.15$	Slănic-Moldova Spa (200-800 ml/day)
BACĂU	$0.04 \pm 0.03$	$0.014 \pm 0.012$	$0.041 \pm 0.012$	$0.058 \pm 0.005$	$0.15 \pm 0.04$	300 steps spring (1,5 - 2 L/day)
BACĂU	$0.09 \pm 0.07$	$0.019 \pm 0.012$	$0.039 \pm 0.004$	$0.07 \pm 0.02$	$0.22 \pm 0.07$	Mineral springs used by the local population
SUCEAVA	$0.13 \pm 0.11$	$0.043 \pm 0.012$	$0.05 \pm 0.03$	$0.02 \pm 0.01$	$0.24 \pm 0.12$	Mineral springs used by the local population
<b>Internal treatment</b>	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	<b>Inhalation of aerosols (10minutes/day) 12-18 days - cure in the spa</b>
BACĂU	$0.144 \pm 0.130$	$0.026 \pm 0.014$	$0.036 \pm 0.022$	$10^{-3}$ ( $1.1 \pm 0.8$ )	$0.21 \pm 0.13$	Slănic-Moldova Spa
SUCEAVA	$0.013 \pm 0.004$	$0.088 \pm 0.014$	$0.055 \pm 0.035$	$10^{-4}$ ( $1.3 \pm 0.7$ )	$0.16 \pm 0.04$	Vatra-Domei Spa
<b>External treatment</b>	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	$\mu\text{Sv}/\text{cure}$	<b>Immersion (250 L mineral water in bath tub) 12-18 days - cure in the spa</b>
SUCEAVA	$10^{-7}$ ( $3.9 \pm 3.6$ )	$10^{-8}$ ( $3.54 \pm 2.21$ )	$10^{-8}$ ( $4.46 \pm 2.71$ )	$10^{-4}$ ( $2.41 \pm 1.05$ )	$10^{-4}$ ( $2.41 \pm 1.05$ )	Vatra-Domei Spa

CONCLUSIONS

The our data contribute to a national database concerning the natural radioactive content of Romanian mineral waters.

An hypothetical person that undergoes a cure of mineral water by ingestion, inhalation and immersion is receiving an average supplementary dose of 3  $\mu\text{Sv}$  over background radiation of 2,450  $\mu\text{Sv}\cdot\text{y}^{-1}$  due to all natural radiation sources in Moldova (North-East part of Romania) (16).

The contribution of mineral water used in therapeutic purposes to the natural irradiation of population is very slight, almost insignificant.

This supports the conclusion that these spring mineral waters can be used without any restrictions for drinking or bathing / washing for medical therapy of ailing persons even other sources of exposure are also taken into account.

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