SOIL AND VEGETATION FROM NOVI PAZAR (SERBIA) AND ROŽAJE (MONTENEGRO): RADIOACTIVITY IMPACT ASSESSMENT*

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Abstract. *Soil samples from Novi Pazar (Serbia) and Rožaje (Montenegro) were analyzed by the ORTEC HPGe detectors with relative efficiencies of 35 and 40 % for radioactivity of ^{226}Ra, ^{232}Th/^{228}Ac, ^{40}K and ^{137}Cs. An average radioisotope activity concentration for Novi Pazar soil was found to be 27.6, 49.5, 585 and 14.9 Bq/kg, respectively; while in Rožaje, ^{137}Cs activity concentration was found to be significantly higher – from 33.9 to 322 Bq/kg. The obtained results were used to estimate hazard indices, such as radium equivalent activity (none of the localities showed a radium equivalent activity higher than 370 Bq/kg) and annual gonadal dose equivalent to natural radioisotopes, as well as external terrestrial gamma absorbed dose rate of ^{226}Ra, ^{232}Th/^{228}Ac, ^{40}K and ^{137}Cs, and corresponding annual effective dose – used to evaluate excess lifetime cancer risk (then compared with the world average of $0.2\cdot10^{-3}$, taking into account external terrestrial radiation – outdoor, i.e., average annual effective dose of 0.07 mSv). Vegetation samples from Rožaje – blackberry (Rubus fruticosus), spruce (Picea abies) and beech (Fagus sylvatica) showed ^{226}Ra activity – 4.03, 1.1 and 0.99 Bq/kg, respectively; ^{232}Th/^{228}Ac – 4.5, <1.22 and 2.89 Bq/kg, respectively; ^{40}K – 152, 98.4 and 79.3 Bq/kg, respectively; ^{137}Cs – 3.05, 3.54 and 5.24 Bq/kg, respectively; whilst in Pinus sylvestris from Novi Pazar, they were – 2.7, 2.11, 163, <0.34 Bq/kg, respectively. Soil-plant radioisotope transfer factors were also estimated, and compared with typical ranges given in the UNSCEAR 2008 report. Since the most important radiation source for all terrestrial biota is the activity from soil, the dose rates are also evaluated using known internal (and external – in soil) radioisotope activity concentrations, as well as corresponding the dose conversion coefficients for external and internal exposure to particular radioisotope.*

Key words: *Novi Pazar, Rožaje, soil-vegetation, radiation risks*

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1. INTRODUCTION

The territories of Novi Pazar (Serbia) and Rožaje (Montenegro) make a borderland between Serbia and Montenegro (illustrated in Fig. 1).

Figure 1. Novi Pazar in Serbia, and Rožaje in Montenegro

Novi Pazar (N. Pazar) municipality has an area of 742 km² and population of 109 327 – based on the Census in 2011, but unofficial information confirm that the population is over 120 000 [1]. On the other hand, Rožaje municipality with an area of 432 km² and population of 22 964 (from the Census in 2011) contributes with around 3.13 % to the entire Montenegro area (13 812 km²), and with 3.7 % to the total Montenegro population (620 029) [2].

As far as is known, radioactivity impacts for soil and vegetation from N. Pazar have not been analyzed before recent start with one locality – Novopazarska Banja, and the stem of "tree of heaven" *Ailanthus altissima* (Swingle, 1916) [3]. In order to provide basic information, soils from the N. Pazar urban area were measured for radioactivity, and some health hazard indices were evaluated (radium equivalent activity, annual gonadal dose equivalent, excess lifetime cancer risk) and presented here.

In the past, several gamma spectrometry measurements were performed in the northern Montenegro using *in situ* [4], HPGe and multidetector (PRIPYAT-2M) spectrometry [5]. Few measurements of radioisotope activities in soil from Rožaje were also performed and showed somewhat higher ^{137}Cs activity. Therefore, soil from three different depths from one locality is additionally analyzed in the present study,

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and the results, together with earlier ones, are used to evaluate hazard indices.

In the light of possible radioecological significance, following biocentric approach in a radioecological research (when animals and plants are considered as targets, not only as contaminants to humans [6]), measurements and analyses of vegetation species from N. Pazar and Rožaje were also carried out. This is particularly because the present radiation protection activities should also be focused on non-human biota, not only on humans.

2. Materials and methods

Nine samples of uncultivated soil from the urban area of N. Pazar (NP1 to NP9; coordinates in Table 1) were sampled in a standard soil sampling procedure – the surface (0-5 cm) layer from a frame of 25 cm x 25 cm [7], while in Rožaje (R; coordinates in Table 1) soil was sampled from (0-5), (5-10) and (10-15) cm in depth (R-1, R-2 and R-3, respectively).

Table 1. Soil sampling localities

Locality	Coordinates
NP1 – Generala Živkovića st.	N 43°08'03.87" E 20°30'40.66"
NP2 – Mihajla Pupina st.	N 43°09'16.89" E 20°31'40.34"
NP3 – Miodraga Jovanovića st.	N 43°08'54.37" E 20°31'07.03"
NP4 – Relje Krilatice st.	N 43°08'46.85" E 20°31'06.36"
NP5 – Gojka Birčanina st.	N 43°08'33.96" E 20°31'04.19"
NP6 – Ramiza Koče st.	N 43°08'24.35" E 20°30'50.45"
NP7 –centre Mladost	N 43°08'19.41" E 20°30'48.82"
NP8 –park	N 43°08'20.13" E 20°31'02.48"
NP9 –Vuka Karadžića st.	N 43°08'18.32" E 20°31'14.91"
R – Rožaje	N 42°56. 296' E 20°12. 402'

The samples were prepared (dried, sieved), weighed (NP – 0.5 kg each; R1 – 0.81 kg, R2 – 1.144 kg, R3 – 1.057 kg), and sealed in Marinelli beakers. Measurements were performed using the ORTEC HPGe detectors (40190, relative efficiency – 40 %; and 30185-S with relative efficiency – 35 %), calibrated using standard mixtures of gamma emitting isotopes in Marinelli beakers (Czech Metrology Institute). Radioisotope activity concentrations were determined in the standard photopeak analyses (using the total net counting rate under the selected photopeak, photoefficiency, gamma ray intensity and mass of the sample) – ^{137}Cs (662 keV); ^{226}Ra, i.e., ^{214}Bi (609 keV); ^{232}Th, i.e., ^{228}Ac (911 keV); ^{40}K (1461 keV). Measuring times were – 10 000 s for each NP sample, and 36 040.7, 27 100.3, 27 000.4 s for R-1, R-2 and R-3, respectively.

The radioisotope activity concentrations are used to calculate the external terrestrial gamma absorbed dose rate at 1 m in air, applying corresponding dose coefficients (in nGy/h per Bq/kg) [8, 9] in

$$D=A(^{226}Ra)\cdot 0.462+A(^{232}Th)\cdot 0.604+A(^{40}K)\cdot 0.0417+A(^{137}Cs)\cdot 0.1243. \quad (1)$$

The annual effective dose was calculated using the conversion coefficient from absorbed dose in air to effective dose of 0.7 Sv/Gy, and *outdoor* occupancy factor of 0.2 [8], i.e.,

$$E = D(\text{nGy/h})\cdot 8760\ \text{h/y}\cdot 0.7\ \text{Sv/Gy}\cdot 0.2. \quad (2)$$

Corresponding excess lifetime cancer risk (*CR*) due to the dose rate E is estimated using [10]

$$CR = E\cdot T\cdot RF, \quad (3)$$

where *T* is lifetime expectancy, and *RF* is risk factor for cancer per Sv. The 70 years lifetime (*T*) is taken into consideration, as well as *RF* of 0.05 for the public – from the ICRP60 recommendations [11].

Since distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform, the radium equivalent activity (Ra_{eq}, in Bq/kg) was calculated by standard formula [12]

$$Ra_{eq}=A(^{226}Ra)+1.43\cdot A(^{232}Th)+0.07\cdot A(^{40}K). \quad (4)$$

As an illustration, the annual gonadal dose equivalent (G, in μSv/y) due to ^{226}Ra, ^{232}Th and ^{40}K in soil has also been calculated using standard relation [13]

$$G=A(^{226}Ra)\cdot 3.09+A(^{232}Th)\cdot 4.18+A(^{40}K)\cdot 0.314. \quad (5)$$

In addition, vegetation samples – leaves/needles of pine *Pinus sylvestris* (L.) (fam. Pinaceae) from N. Pazar, as well as stem of blackberry *Rubus fruticosus* (L.) (fam. Rosaceae), bark of beech *Fagus sylvatica* (L.) (fam. Fagaceae) and leaves/needles of spruce *Picea abies* (L.) Karst (fam. Pinaceae) from Rožaje, were analyzed for radioactivity of natural ^{226}Ra (^{214}Bi), ^{232}Th (^{228}Ac), ^{40}K, and anthropogenic ^{137}Cs.

Transfer factor (*TF*) for particular radioisotope has been evaluated by the ratio: activity concentration in vegetation sample (Bq/kg)/activity concentration in soil (Bq/kg).

As is emphasized in the UNSCEAR 2008 report related to the effects of ionizing radiation on non-human biota [14], the most important source of radiation for all terrestrial biota (including here considered vegetation) is the soil activity. Therefore, the dose rate can be calculated using [14]

$$D = \sum_i \left| DCC_{ext,i} \cdot A_{soil,i} + DCC_{int,i} \cdot A_i \right|, \quad (6)$$

where $DCC_{ext,i}$ is the dose conversion coefficient for the radioisotope *i* – external exposure (in μGy/h per Bq/kg); $A_{soil,i}$ is the activity concentration of radioisotope *i* in soil (in Bq/kg); $DCC_{int,i}$ is weighted dose conversion coefficient for internal exposure to radioisotope *i* (in μGy/h per Bq/kg) – assuming a homogeneous activity distribution in the organism; A_i is the radioisotope *i* internal activity concentration in vegetation sample (in Bq/kg). The DCC_{ext}s given in the

UNSCEAR 2008 report, for ^{137}Cs, ^{226}Ra and ^{232}Th for *on soil* reference organism (pine tree), are: $1.1{\cdot}10^{-4}$, $3.4{\cdot}10^{-4}$, $4.3{\cdot}10^{-8}$ µGy/h per Bq/kg, respectively, as $DCC_{int}s$ – $3.5{\cdot}10^{-4}$, $1.4{\cdot}10^{-1}$, $2.3{\cdot}10^{-2}$ µGy/h per Bq/kg, respectively [14]. The DCC_{ext} and DCC_{int} for ^{40}K in terrestrial plants found in literature [15] are also used to evaluate dose rate levels due to this radioisotope: $\approx 2.9{\cdot}10^{-4}$ and $\approx 3.9{\cdot}10^{-4}$ µGy/h per Bq/kg, respectively.

3. Results and Discussion

3.1. Soil measurements

Table 2 shows the results of radioisotope activity measurements in N. Pazar and Rožaje soils.

Table 2. Results of soil measurements

Soil	A(^{137}Cs), Bq/kg	A(^{226}Ra), Bq/kg	A(^{232}Th), Bq/kg	A(^{40}K), Bq/kg
NP1	20.3±0.9	22.6±1.2	44.8±2.4	481±18
NP2	17.8±0.8	28.9±1.3	47.8±2.5	569±21
NP3	11.5±0.7	29.3±1.3	57.9±2.8	569±21
NP4	11.9±0.6	19.2±1.0	37.2±2.1	524±19
NP5	17.8±0.8	29.5±1.3	48.8±2.6	607±22
NP6	16.6±0.8	28.3±1.3	47.0±2.6	593±22
NP7	17.2±0.8	35.0±1.6	63.2±3.0	672±24
NP8	18.3±0.8	30.4±1.4	54.1±2.9	637±23
NP9	2.21±0.39	25.4±1.3	44.4±2.4	613±23
R-1	322±10	28.9±1.0	39.8±1.5	319±11
R-2	70.6±2.3	24.8±0.9	39.4±1.4	344±12
R-3	33.9±1.1	22.6±0.9	37.4±1.6	356±12

The highest ^{137}Cs activity concentration measured in the sample NP1 (20.3 Bq/kg) is lower than, for example, that found in the Lazarevac soil (38.1 Bq kg^{-1} [16]), and many folds lower than one measured in Rožaje top soil (322 Bq/kg). As follows from the Table 2 data, extremely low ^{137}Cs level was found at the locality NP9 (2.21 Bq/kg), while its average activity concentration was calculated to be 14.8 Bq/kg, with a standard deviation and median – 5.6 and 17.2 Bq/kg, respectively.

An analysis of ^{226}Ra activity concentrations in N. Pazar soil showed – it ranges from 19.2 to 35 Bq/kg (which is the world median of mean concentrations [8]), with an average of 27.6 Bq/kg, and standard deviation and median of 4.63 and 28.9 Bq/kg, respectively. A mean activity concentration of ^{232}Th (49.5 Bq/kg, with a standard deviation of 7.81 Bq/kg) is found to be higher than the world median of mean concentrations (30 Bq/kg [8]), with the range and median of (37.2-63.2) and 47.8 Bq/kg, respectively. Potassium-40 activity concentrations also showed an average value (585 Bq/kg, with a standard deviation of 57.7 Bq/kg) and median (593 Bq/kg) higher than the world median of mean concentrations (400 Bq/kg [8]).

A cumulative activity concentration at each N. Pazar locality with a contribution of particular radioisotope (in %) is shown in Fig. 2.

The dose rates (D and E, calculated using (1) and (2), respectively) are reported in Fig. 3; and showed the range, average, standard deviation and median of – (54.7-84.5), 68.9, 8.8 and 68.2 nGy/h, respectively (D), and (0.07-0.1), 0.08, 0.01 and 0.08 mSv/y, respectively (E).

The absorbed dose rate average was found to be slightly higher than the average absorbed dose rate in 7 South Europe countries (62 nGy h^{-1} [8]), or, for example, in Belgrade (60.5 nGy h^{-1} [17]). This average (but also median) value is somewhat higher than the global average (57 nGy h^{-1} [8]).

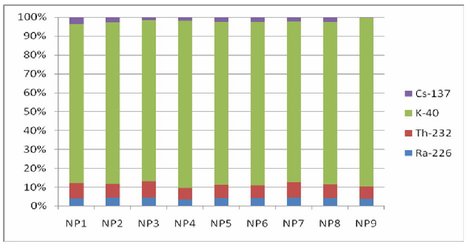

Figure 2. A contribution of radioisotopes to the cumulative activity

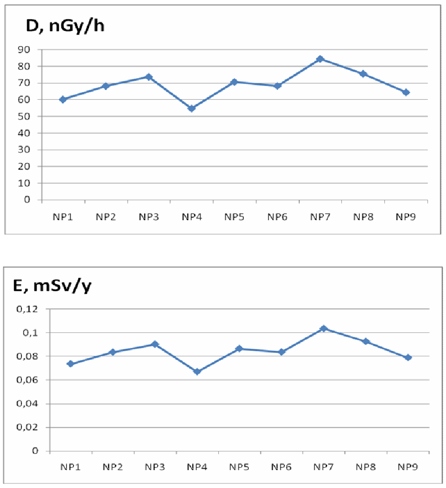

Figure 3. External terrestrial gamma dose rates in N. Pazar: absorbed at 1 m above the ground (D), and annual effective (E)

The highest determined annual effective dose is for one order of magnitude less than 1 mSv/y, while an E average is slightly higher than the global average, i.e., average annual effective dose of 0.07 mSv from natural radiation sources – external terrestrial radiation, *outdoor* [8]. Consequently, excess lifetime cancer risk (eq. (3)), shown in Fig. 4, was found to be within the range from $2.35{\cdot}10^{-4}$ to $3.63{\cdot}10^{-4}$, with an average, standard deviation and median of 2.96, 0.38 and 2.93 $({\cdot}10^{-4})$, respectively. The *CRs* average for the world is $2.45{\cdot}10^{-4}$, taking into consideration annual effective dose of 0.07 mSv [8], while, for example, in Kirklareli, Turkey it is from 4.3 to 6.1 $({\cdot}10^{-4})$ [10].

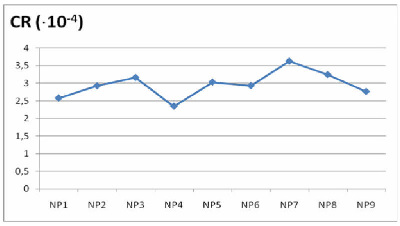

Figure 4. Excess lifetime cancer risk – N. Pazar

The annual gonadal dose equivalent due to natural radioisotopes (*G*, eq. (5)) is presented in Fig. 5, together with radium equivalent activity (Ra_{eq}, eq. (4)); showing minimum, maximum, average, standard deviation and median – 0.38, 0.58, 0.48, 0.06, 0.47 mSv/y, respectively (*G*), and 109, 172, 139, 18.6 and 137 Bq/kg, respectively (Ra_{eq}).

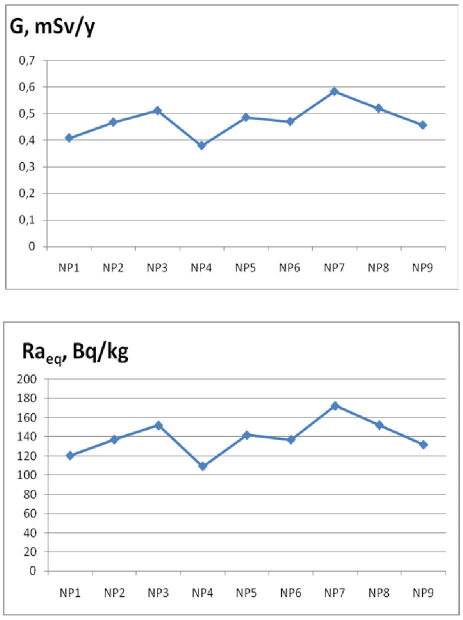

Figure 5. Annual gonadal dose equivalent and radium equivalent activity – N. Pazar

For a comparison, the top Rožaje soil (R-1 in Table 2) showed the *G* and Ra_{eq} value of around 356 µSv/y and 108 Bq/kg, respectively; *D* and *E* of 90.7 nGy/h, and 111 µSv/y, respectively; i.e., higher than those for N. Pazar – resulting in a higher excess lifetime cancer risk ($3.89 \cdot 10^{-4}$), which is lower than an average found for Nikšić in Montenegro ($4.4 \cdot 10^{-4}$) [18].

A previous research showed that in Montenegro soils ^{137}Cs dominantly originated from the Chernobyl accident, and its activity decreases with soil depth (i.e., it is mostly still in the surface soil layer [19]), which is also confirmed in the present study for the Rožaje locality (R).

During *in situ* measuring campaign in 1994 [4] two measuring points from the Rožaje region were included (Bašća and Kozare) and showed (326±33) and (363±33) Bq/kg of ^{137}Cs, respectively; as well as ^{238}U – (15±2) and (14±2) Bq/kg, respectively; ^{232}Th – (17±2) and (14±2) Bq/kg, respectively; ^{40}K – (207±22) and (237±23) Bq/kg, respectively.

From the Rožaje area where spruce and beech had been sampled (locality *R'*), surface (0-5 cm) soil was previously analyzed using the PRIPYAT-2M six-detector spectrometer, showing ^{137}Cs, ^{226}Ra/^{214}Bi, ^{232}Th/^{228}Ac, ^{40}K activity of (221±11), (36.7±2.5), (45.2±2.8) and (409±15) Bq/kg, respectively; and Ra_{eq}, *G*, *D*, *E*, *CR* – 130 Bq/kg, 431 µSv/y, 88.8 nGy/h, 109 µSv/y, $3.81 \cdot 10^{-4}$, respectively.

3.2. Vegetation measurements

The results of vegetation measurements are reported in Table 3. Masses of pine, blackberry, beech and spruce samples were 181.17, 171.22, 134.7 and 203.4 g, respectively; as measuring times – 53 842, 73 321, 150 179 and 46 240 s, respectively.

Table 3. Results of vegetation measurements

Sample	A(^{137}Cs), Bq/kg	A(^{226}Ra), Bq/kg	A(^{232}Th), Bq/kg	A(^{40}K), Bq/kg
P. sylvestris	<0.34	2.7±0.18	2.11±0.58	163±7
R. fruticosus	3.05±0.23	4.03±0.31	4.5±0.64	152±6
F. sylvatica	5.24±0.32	0.99±0.12	2.89±0.84	79.3±3.7
P. abies	3.54±0.21	1.1±0.12	<1.22	98.4±4.8

The pine sample was taken from the locality NP3 (lower branches with leaves; while soil was sampled at a distance of 1.5-2 m from the tree base). The *TF* (i.e., activity concentration ratio: *P. sylvestris*/soil) was found to be <0.029, 0.092, 0,036 and 0.286 – for ^{137}Cs, ^{226}Ra/^{214}Bi, ^{232}Th/^{228}Ac and ^{40}K, respectively.

In *R. fruticosus* (sampled at the R locality) considering surface soil layer R-1, the *TFs* are 0.009, 0.13, 0.113 and 0.476, respectively; whilst considering average activities in three soil layers (R-1 – R-3): 0.021, 0.15, 0.115 and 0.447, respectively.

In *F. sylvatica* (the R' locality) they were found to be 0.024, 0.027, 0.064 and 0.194, respectively; as in *P. abies* 0.016, 0.03, <0.027 and 0.241, respectively.

It should be noted that data for ^{40}K (a largest source of natural radioactivity in non-human biota) are given as an illustration only.

Typical ranges for soil-plant *TFs* for Ra and Cs given in the UNSCEAR 2008 report are 0.001-0.1 [14]. In that view, the *R. fruticosus* radium *TF* is slightly higher, and should be considered in a further study.

It is important to point out that these results cannot be used for the whole *P. sylvestris* (since related to leaves) which can also accumulate radioisotopes in root, stem, cones; for whole *R. fruticosus,* which can also accumulate radioisotopes in root, leaves and fruit itself, or for whole *F. sylvatica* and *P. abies* which also need further research. For example, nominal *TF* values for reference organism, pine tree (vegetation (Bq/kg)/soil (Bq/kg)), are 0.2, 0.0007 and 0.001 – for cesium, radium and thorium, respectively [14], while typical ranges of aggregated *TFs* for ^{137}Cs from soil to vegetation (Bq/kg – vegetation, per Bq/m^2 – soil) for *R. fruticosus* fruit: 0.006-0.05, for *Pinus sp.* needles: 0.001-0.04, *Picea sp.* needles: 0.0006-0.02; *Fagus sp.* bole wood: 0.001-0.002 and leaves: 0.002-0.003 [14].

To illustrate radiation exposure levels, the total dose rates were estimated using eq. (6), assuming a homogeneous activity distribution in the organisms.

From a consideration of the areas where vegetation species were sampled, i.e., NP3 – *P. sylvestris*, R – *R. fruticosus* (an average radioisotope activity concentration has been used in calculating dose rates), and R' – *F. sylvatica*, *P. abies*; an external exposure to radium is found to be around 9.96, 8.64 and 12.5 nGy/h, respectively, thorium – 2.49, 1.67 and 1.94 pGy/h, respectively, cesium – 1.26, 15.6 and 24.3 nGy/h, respectively; potassium – 165, 98.6 and 119 nGy/h, respectively. The total external exposure (^{137}Cs, ^{226}Ra, ^{232}Th, ^{40}K) on these three localities would be 0.18, 0.12 and 0.15 μGy/h, respectively.

Internal exposure of *P. sylvestris*, *R. fruticosus*, *F. sylvatica* and *P. abies* to considered radioisotopes is evaluated to be – <0.112, 0.728, 0.238 and <0.222 μGy/h, respectively; which means total exposure rate (external and internal) of <0.666, 0.851, 0.393 and <0.377 μGy/h, respectively.

Comparing these results with ones obtained in an evaluation of doses to non-human biota (terrestrial plants) at Trombay, Mumbai (India) [20], where radiation exposure was found to be 437.2-1044 μGy/y (average: 632.8 μGy/y) for ^{40}K, 2379.8-299763.9 μGy/y (average: 48769 μGy/y) for ^{232}Th, 21.3-2392.2 μGy/y (average: 691.23 μGy/y) for ^{137}Cs; doses to terrestrial biota determined in the present study can be considered as significantly less.

The highest dose rate (*R. fruticosus*) of 0.02 mGy/d is significantly below the threshold dose for terrestrial plants (10 mGy/d]), i.e., below the dose interval (2.5-25) mGy/d from recent literature compilation (ERICA project) – as explained in [6], when effects on plants under chronic exposure could be expected (growth reduction, etc.).

4. Conclusions

None of the considered localities in N. Pazar – Serbia and Rožaje – Montenegro showed a radium equivalent activity higher than 370 Bq/kg. Absorbed dose rates from terrestrial gamma radiation showed an average and median slightly higher than the world's median of average values reported in the UNSCEAR 2000 (57 nGy h^{-1}). The annual gonadal dose equivalent for soil samples from N. Pazar studied in this work proved to be higher than the world average, while in soil from Rožaje, in the case of one locality, it is comparable with the world's average. With life expectancy taken to be 70 years, a mean excess lifetime cancer risk was found to be $2.8 \cdot 10^{-4}$ for N. Pazar, as well as $3.81 \cdot 10^{-4}$ and $3.89 \cdot 10^{-4}$ for Rožaje.

Transfer factors for ^{137}Cs, ^{226}Ra/^{214}Bi, ^{232}Th/^{228}Ac from soil to vegetation ranged from 0.009 (for ^{137}Cs from soil to *R. fruticosus*) to 0.13 (for ^{226}Ra from soil to *R. fruticosus*).

The total dose rate – internal and external exposure of *P. sylvestris*, *R. fruticosus*, *F. sylvatica* and *P. abies* to ^{137}Cs, ^{226}Ra/^{214}Bi, ^{232}Th/^{228}Ac and ^{40}K, is found to be less than 0.021 mG/d (<0.666, 0.851, 0.393 and <0.377 μGy/h, respectively), i.e., many folds less than the threshold dose for terrestrial plants (10 mGy/d).

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References

1. Official site: www.novipazar.rs (in Serbian).
2. MONSTAT, "Statistical Yearbook of Montenegro", Statistical Office of Montenegro, Podgorica, 2012.
3. I.Antović, D. Stojanović, N. Svrkota, R. Žižić, M. Hadžibrahimović, "Opening radioecological research in Novi Pazar – territory of Novopazarska Banja," *Proc. 27th Symposium of the Radiation Protection Society of Serbia and Montenegro*, Vrnjačka Banja – Serbia, pp. 72-75, 2013. (in Serbian)
4. P. Vukotić et al. "Background gamma-radiation in Montenegro," *Proc. IRPA Regional Symposium on Radiation Protection in Neighbouring Countries of Central Europe*, Prague, Czech Republic, pp. 477-479, 1997.
5. N. M. Antovic, N. Svrkota, I. Antovic, "Measuring ^{226}Ra and ^{232}Th activity in soil and vegetation samples using a method of double γ-coincidences, " *J. Radioanal. Nucl. Chem.*, vol. 283(2), pp. 313-318, 2010.
6. International Union of Radioecology, http://iur-uir.org/upload/About%20IUR/radioecology_oslo_presentation2014.pdf, 2014.
7. HASL-300, "EML Procedures Manual", Environmental Measurements Laboratory, U.S. Department of Energy, 28 Edition, 1997.
8. UNSCEAR, "Sources and Effects of Ionizing Radiation. Annex B: Exposure from natural radiation sources", United Nations, New York, 2000.
9. E. Kapdan, A. Varinlioglu, G. Karahan, "Radioactivity levels and health risks due to radionuclides in the soil of Yalova, northwestern Turkey," *Int. J. Environ. Res.*, vol. 5(4), pp. 837-846, 2011.
10. H. Taskin et al. "Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey," *J. Environ. Radioactiv.*, vol. 100(1), pp. 49-53, 2009.
11. ICRP Publication 60, "1990 Recommendations of the International Commission on Radiological Protection", 21/1-3, 1991.
12. J. Beretka, P. J. Mathew, "Natural radioactivity of Australian building materials, industrial wastes and by-products," *Health Phys.*, vol. 48(1), pp. 87-95, 1985.
13. W. Arafa, "Specific activities and hazards of granite samples collected from the eastern desert of Egypt," *J. Environ. Radioactiv.*, vol. 75(3), pp. 315-327, 2004.
14. UNSCEAR, "Sources and effects of ionizing radiation. Annex E: Effects of ionizing radiation on non-human biota", 2008 Report to the General Assembly with Scientific Annexes, United Nations, New York, 2011.
15. B. D. Amiro, "Radiological dose conversion factors for generic non-human biota used for screening potential ecological impacts," *J. Environ. Radioactiv.*, vol. 35, pp. 37-51, 1997.

16. S. S. Nenadovic, M. T. Nenadovic, I. S. Vukanac, M. O. Omerasevic, Lj. M. Kljajevic, "Radiological hazards of ^{137}Cs in cultivated and undisturbed areas," *Nucl. Technol. Radiat. Prot.*, vol. 26(2), pp. 115-118, 2011.
17. Lj. Jankovic Mandic, S. Dragovic, "Assessment of terrestrial gamma exposure to the population of Belgrade (Serbia)," *Radiat. Prot. Dosim.*, vol. 140(4), pp. 369-377, 2010.
18. N. M. Antović et al., "Radioactivity impact assessment of Nikšić region in Montenegro," *J. Radioanal. Nucl. Chem.*, vol. 302 (2), pp. 831-836, 2014.
19. N. M. Antovic, P. Vukotic, N. Svrkota, S. K. Andrukhovich, "Pu-239+240 and Cs-137 in Montenegro soil: their correlation and origin," *J. Environ. Radioactiv.*, vol. 110, pp. 90-97, 2012.
20. R. K. Singhal, K. Ajay, N. Usha, A. V. R. Reddy, "Evaluation of doses from ionizing radiation to non-human species at Tromay, Mumbai, India," *Radiat. Prot. Dosim.*, vol. 133(4), pp. 214-222, 2009.