ECOLOGIA BALKANICA

2020, Special Edition 3 pp. 163-168

Observed Reduction by a Factor of 10 in the Whole-body Total β-activity of Small Mammals from Alpine Ecosystems in Rila Mountain, Bulgaria

Peter Ostoich[1*], Michaela Beltcheva[1], Roumiana Metcheva[1], Iliana Aleksieva[1], J. A. Heredia-Rojas[2], Elena Geleva[3], Christo Angelov[3]

1 - Institute of biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., Sofia 1000, BULGARIA
2 - Autonomous University of Nuevo León, Faculty of Biological Sciences. Av. Pedro de Alba y Manuel L. Barragán s/n Cd. Universitaria, C.P. 66455, San Nicolás de los Garza, Nuevo León, MEXICO
3 - Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72 Tzarigradsko Shaussee, Sofia 1784, BULGARIA
[*]Corresponding author: p.ostoich@gmail.com

Abstract. Radio-ecological studies were conducted on small mammal species at two sampling locations in Rila Mountain, Bulgaria. As monitor species, the snow vole (*Chionomys nivalis* Martins, 1842) and wood mouse (*Apodemus sp.* – *Apodemus flavicollis* Melchior, 1834, and *Apodemus sylvaticus* Linnaeus, 1758) were sampled in the vicinity of Musala Peak (2925 m a. s. l.), and wood mouse (*Apodemus sp.*) and bank vole (*Myodes glareolus* Schreber, 1780) were sampled from the area of Skakavtsite (1450 m a. s. l.). Total β-activity was measured by use of a low-background beta counter (LAS 3A level activity system with 30% efficiency on ^{40}K). The values in the investigated rodents show high variation: from 144 up to 1081 Bq/kg without strong region and species dependence. These data fall within the normal range for non-polluted environments. The results were compared to data obtained on Rila Mountain in the period 1993-1996. A reduction by a factor of 10 was observed over the two-decade time period, attributable in part to the decay of deposited anthropogenic β-emitters after the Chernobyl accident in 1986. The results are consistent with models and projections for the reduction of the specific activity of radionuclides in Europe as a function of time.

Key words: radioecology, β-activity, biomonitoring, small mammals.

Introduction

Anthropogenic deposition of radionuclides is a critical problem, particularly in heterogeneous landscapes, such as mountainous regions. Recent studies demonstrate demonstrated that high alpine environments are negatively influenced by environmental pollution. Atmospheric deposition of contaminants at high elevations is greater than those of low elevation regions, because of orographic effects, cloud deposition, wind speed etc. (Lovett &

Kinsman, 1990). The use of living organisms as sentinel species in monitoring environmental pollution has been extensively developed during the last decades. Small mammals such as rodents were selected for use as bioindicators due to their positions in the food chain, rapid maturation, large population numbers, wide geographical distribution, and biological reaction to environmental changes. They have been used for this purpose for a long time, with body burdens of toxicants being determined in either the whole body or in specific target organs and tissues (Martin & Coughtry, 1982; Wern, 1986; Talmage & Walton, 1991; Pascoe et al., 1995). Bulgarian studies have been conducted, focusing specifically on the whole-body total β-activity of several monitor species, including *Apodemus* species, and, especially in Rila Mountain, the snow vole (*Chionomys nivalis* Martins, 1842) (Iovtchev et al., 1995; 1996; Metcheva et al., 1995; 2008). The isotopes Cs-137, Cs-134 and Sr-90 present in the biosphere are the basic anthropogenic β-emitters (Thorn & Vennard, 1976, Metcheva et al., 1995). Additionally, I-131 and I-133 also emit β-particles but are very short-lived; an important natural source is K-40, but it is a relatively weak emitter, responsible for only a small percentage of the dose, as well as a small percentage of measurable β-activity. The total β-activity in mammals has to be less than 4.8 Bq/g. (Thorn & Vennard, 1976). If it is higher, it is obligatory to measure concentrations of each radionuclide.

The primary sources of residual α and β-activity are the naturally occurring radioisotopes of uranium and thorium, and any residual fallout from anthropogenic weapons testing and the Chernobyl reactor accident in 1986. Nowadays the main source of anthropogenic β-activity in Europe is fallout due to the Chernobyl accident in 1986 (Chesser et al., 2000; 2006). The immediate aftermath of the reactor accident created unique conditions of uneven deposition of radionuclides over Central and Eastern Europe, with the most affected areas being adjacent to the power plant itself (Ukraine, Belarus, Russia) and areas in Central Europe (Salzburg, Austria) and Scandinavia (Northern Sweden) being contaminated to a different degree due to changing weather paterns. There is a scarcity of data regarding radionuclide deposition in Bulgaria, with most of the available values coming from routine radiation monitoring in the area around Kozloduy NPP and the measurements contucted during the French-Bulgarian joint project "Musala OM2", which took place during the 1990s (Iovtchev et al., 1995; 1996; Metcheva et al., 1995; Tsibranski, 2014). The current study is a contemporary re-assessment of the radiological situation in Rila Mountain with respect to small mammal species, and its main aim is to compare data recorded more than 20 years ago to presently obtained results.

Materials and Methods

Monitor species of small mammals were caught in the summer seasons of 1993-1996 and 2017 and 2018 using live-bait and snap traps on the territory of Rila Mountain at two different altitudes – the peak of Musala 2925 m a.s.l., and the locality Skakavtsite (between Beli Iskar Village and Beli Iskar Reservoir), 1450 m a.s.l (Fig. 1).

The following rodent species were captured during the investigated periods: wood mouse (*Apodemus sp.*) and bank vole (*Myodes glareolus* Schreber, 1780) from Skakavtsite, and snow vole (*Chionomys nivalis*) and wood mouse (*Apodemus sp.*) from the peak of Musala. The number of the caught animals is presented in Table 1. Animals were terminated in a humane manner according to the National and European laws on animal welfare.

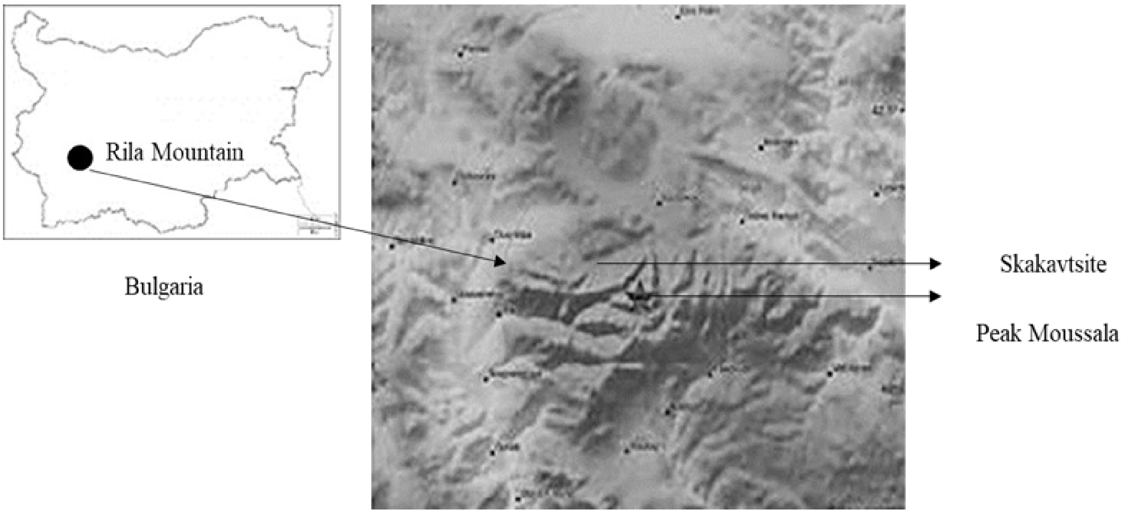

Fig. 1. Trapping points in Rila Mountain during the investigated period.

All collected animals were dissected to remove the intestinal tract and its contents, as well as most internal organs and tissues — liver, kidneys, spleen, and bones. The samples were oven-dried at 60°C for approximately three days to obtain dry weight and analyzed for total β-activity (Iovtchev et al., 1996). All collected samples were treated according to the standard procedure: mineralization at 400°C for 4 hours and measurements of material (13.26 mg/cm) by means of a LAS 3A low level activity system (30% efficiency on ^{40}K and background 1 cpm-1) (Iovtchev et al., 1996). Total β-activity was measured using a low-background beta counter (LAS 3A level activity system with 30% efficiency on ^{40}K and background 1 cpm, INRNE) and was compared with measurements of a ^{40}K standard prepared and measured in the same manner. The background of the detector was determined by counting an empty planchette for 900 min (Iovtchev et al., 1996). Data were standardized and one-way analysis of variance (ANOVA) was used to determine any significant differences among independent groups of parameters. Results are expressed as mean ± standard deviation. *p* -values less than 0.05 were considered to be statistically significant. Presently obtained results were compared to data, obtained in the same manner more than 20 years ago.

Results

The results for total β-activity are presented in comparison with those obtained in the 1993-1996 investigation period (Table 2).

Table 1. Number of the caught individuals of the investigated small rodent species during the two studied periods.

Location	Skakavtsite		Musala	
	1993-1996	2017- 2018	1993-1996	2017- 2018
Species	n	n	n	n
Apodemus sp.	16	13	14	12
Myodes glareolus	15	22	-	-
Chionomys nivalis	-	-	20	12

Table 2. Total β-activity in Bq/kg in the whole body of monitor species of small rodents from the two investigated areas in Rila Mountain in the beginning and the end of the twenty-year investigation period.

Skakavtsite	β activity mean ± SD		Musala	β activity mean ± SD	
	1993-1996	2017- 2018		1993-1996	2017- 2018
Apodemus sp.	3000.1±160	366.3 ± 8.1	*Apodemus sp.*	2520.3±160	230.3 ± 7.2
Myodes glareolus	2710.8±130	524.2 ± 5.3	*Chionomys nivalis*	3270.5±150	382.0 ± 8.3

The results for total β-activity in the investigated internal organs and tissues in all the monitor species show higher activity in muscles -about 5000 Bq/kg (1993-1996) and 420 Bq/kg (2017- 2018). Similar but lower were these values for the liver – about 4000 Bq/kg and 310 Bq/kg respectively. Few species-specific differences in the quantities were found among investigated animals. The lowest β-activity was found in the bones - about 1000 Bq/kg and 120 Bq/kg respectively. In all cases it is possible to conclude that the accumulation of the total β-activity in the internal organs follows the trend: muscles > liver >bones.

Discussion

The obtained data are consistent with models for the dynamics of radionuclide deposition, mobility and decay within terrestrial ecosystems (Beresford et al., 2008).

When investigating wild rodents from the Chernobyl exclusion zone, an international team obtained similar patterns of results during the late 1990s-early 2000s (Chesser et al., 2000; 2006). Investigations in areas with different degrees of contamination showed that *M. glareolus* is particularly prone to bioaccumulation of cesium radionuclides (^{134}Cs and ^{137}Cs) which explains the high absorbed dose in these animals (Chesser et al., 2000; 2006; Beresford et al, 2008). *M. glareolus* is a predominantly herbivorous species. Since it feeds on the green parts of plants, which preferentially accumulate cesium, it is expected to exhibit higher uptake of ^{134}Cs and ^{137}Cs than, for example, *Ap. flavicollis*. This can help explain why the observed reductions in total β-activity are more significant for *Apodemus* species (about tenfold) than they are for *M. glareolus* (about 5 times).

What can be expected for the future? The main residual radionuclides from Chernobyl at present are ^{137}Cs (half-life of about 30 years) and ^{90}Sr (half-life of about 29 years). The majority of other radionuclides, released into the atmosphere during the accident, have either decayed, or are not biologically significant (for instance, Krypton-85 has a half-life of about 10 years, but is a noble gas, hence cannot be expected to bioaccumulate). This means that cesium and strontium are the most significant anthropogenic β-emitters radionuclides in the environment Metallic strontium is only weakly soluble in water, leaving ^{137}Cs as the main circulating anthropogenic β-emitter in terrestrial ecosystems. The importance of other long-lived radionuclides, such as ^{241}Am, and plutonium isotopes to internal β-paricle dose will remain insignificant (Labunska et al., 2016). This means that in the future, due to the leading role of ^{137}Cs as anthropogenic β-emitter, researchers are likely to see progressive decrease in β-activity in the European terrestrial small rodents, which will be more pronounced in *Apodemus* species and less pronounced in *M. Glareolus*.

Conclusions

The current investigation reveals a decrease in measured whole-body total β-activity in small rodents from alpine ecosystems in Rila Mountain, Bulgaria. This decrease is more pronounced in

Apodemus species and *Ch. nivalis* and less pronounced in *M. glareolus*, a phenomenon attributable to the higher significance of ^{137}Cs as a component of an overall decreasing contamination by anthropogenic β-emitters.

Acknowledgements

This work is supported by the National Science Fund of Republic of Bulgaria through the project DN 04/1, 13.12.2016: "Study of the combined effect of the natural radioactivity background, the UV radiation, the climate changes and the cosmic rays on model groups of plant and animal organisms in mountain ecosystems".

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Received: 17.07.2020
Accepted: 18.12.2020