Original Research

Radiocesium Contamination of Red Deer (*Cervus Elaphus*) in Northeastern Poland

K. Zalewski*, K. Szymczyk-Kobrzyńska

Department of Biochemistry, Faculty of Biology, Warmia and Mazury University,
Oczapowskiego 1a, 10-718 Olsztyn-Kortowo, Poland

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Abstract

This paper presents the results of a study on the ^{137}Cs content in liver, kidneys and biceps muscles of red deer (*Ceravus elaphus*) obtained in Warmia and Mazury in 2000/2001. 93 samples from 51 red deer shot in the communes of Reszel, Lelkowo, Olecko, Kętrzyn, Pisz, Ruciane Nida, Ryn, Szczytno, Orzysz, Rozogi, and Olsztynek were analyzed. Concentrations of radiocesium in several samples of muscle tissue of red deer obtained from the European part of Russia was determined for reference. In Warmia and Mazury the average concentrations of ^{137}Cs were 20.48 Bq/kg in muscle, 13.26 Bq/kg in liver, and 18.74 Bq/kg in kidneys. As such, these were very low figures. It was only in a few samples of red deer tissues obtained at two locations (Olsztynek, Zaporowo) that the levels of this radionuclide were elevated compared to those from other sites. The least radioactive were samples collected from carcasses of calves, in contrast to those taken from bucks, which contained the highest levels of radiocesium. A wide range of differences in the determinations was obtained. For example, concentrations of radiocesium in muscle tissues varied from 1.91 to 28.55 Bq/kg for calves, 0.91 to 79.20 for does and 2.69 to 137.20 Bq/kg for bulls. The ^{137}Cs levels in red deer's potential foodstuffs also varied from region to region, although it was to a certain extent positively correlated with the amounts of radiocesium determined in the red deer carcasses obtained in these areas.

Keywords: ^{137}Cs, red deer, Warmia and Mazury

Introduction

In contrast to farm animals, animals living in the wild depend exclusively on the natural resources and the condition of soils present in their habitats. The enviornmental pollution caused by harmful substances affects the animals inhabiting a given territory via the food or water they ingest and the air they breath [1]. As early as the late 19th century wild animals were recognized as good bioindicators of environmental conditions. Over the last twenty years this issue has been strongly emphasised by several authors, including Drescher-Kaden [2], Tataruch [1, 3, 4, 5], Tataruch *et al.* [6], Johanson and Bergstrőm [7], and Zibold *et al.* [8]. In Poland, the matter has been investigated by Falandysz [9, 10].

*Corresponding author; e-mail: k.zalewski@uwm.edu.pl

Contamination of the environment by non-organic substances is largely caused by ashes generated from burning huge amounts of fuels, especially black coal. Concentrations of heavy metals and radioactive isotopes in ashes exceed several-fold the levels of these elements in the fuels they have been generated from.

In nature, radionuclides occur as natural and artificial elements, the latter being created as a result of nuclear fission. Artificial radioactive elements gained in importance following the explosion of the first atomic bomb and several breakdowns in nuclear power stations. The state of the natural environment in north-eastern Poland (known as the "green lungs" of Poland) and some other regions of Europe was badly affected by the Chernobyl nuclear disaster, when large areas (about 25,000 km^2) were contaminated by several ra-

Table 1. Red deer, roe deer and wild boar shot in Warmia and Mazury in the hunting season 2000/2001 (number of animals).

Species	Red deer (*Cervus elaphus*)			Roe-deer (*Copreolus copreolus*)			Wild boar (*Sus scrofa*)			Together	
Sex	Bucks	Does	Calves	Deer	Goats	Goating	> 70 kg and boars	2 years old	Piglets	Units	kg
Mean in 2000/2001	1.599	2.009	875	5.013	5.995	2.460	1.301	3.595	5.557	28.404	979.901
Species together	4.483 units, 359.626 kg			13.468 units, 216.115 kg			10453 units, 403.897 kg			-	-

dionuclides, whose concentration in soil was still high 11 years after the accident (Fig. 1). Some of these substances (for example ^{131}I) have already disappeared completely because of their short radioactivity decay (½ T). Others (such as ^{137}Cs, ^{90}Sr), after a long half-life, cannot yet be neglected in terms of environmental hygiene. Another reason why we have undertaken a study on wild animals is that northeastern Poland is the region where large numbers of wild game are hunted (Table 1) and consumed. Poland's expected accession to the European Union has added importance to research on the effect of harmful substances on animals living in the wild. One part of such studies involves comparisons of the 'poisoning' of wild animals and contamination of the region they inhabit. And the contamination caused by ^{137}Cs in Warmia and Mazury was considerable. Seven years after the Chernobyl accident, soil contamination still reaches levels of 2 to 4 kBq/m^2 in a soil layer to 10 cm depth.

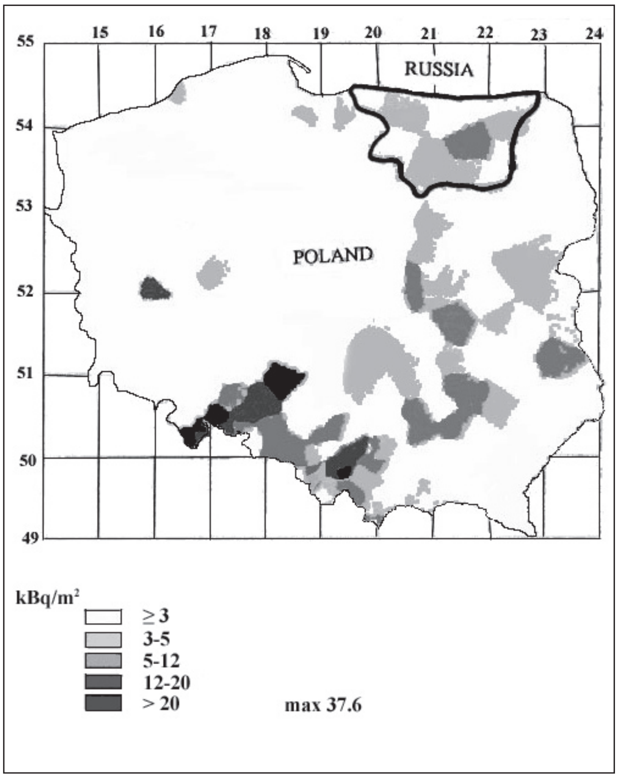

Fig. 1. ^{137}Cs concentration in soil –1997 year. (Jagielak et al. [17]).

Material and Methods

Concentrations of ^{137}Cs were determined in livers, kidneys and bicep muscles of red deer from the district of Olsztyn, a town situated in northeastern Poland (Fig. 2). Samples were collected from September 2000 to February 2001. On one occasion 5 samples (muscle tissue only) were received from carcasses of red deer shot at that time in the west of Russia (a purchase centre in Moscow). The concentration of radiocesium was determined in a total of 51 red deer in 93 samples, including 35 muscle, 29 liver and 29 kidney tissues. In the late autumn of 2001 and in the winter and spring of 2002 samples of the plant material eaten by red deer were collected to determine cesium levels.

^{137}Cs concentrations were determined by gamma spectrometry [11]. The gamma spectrometer consisted of a high-purity germanium detector placed inside a lead shield with 10-cm thick walls lined with a 2-mm layer of copper. The detector was connected to a multichannel analyzer. Calibration of the gamma spectrometer was performed with standard solutions from the U.S. Environmental Protection Agency (EPA) Environmental Monitoring Systems Laboratory – Las Vegas. Standard solutions included the following radionuclides: ^{22}Na, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{88}Y, ^{133}Ba, ^{134}Cs, ^{137}Cs and 144Ce. Counting time was chosen to maintain the counting error for the 137Cs<10% at 1.64σ.

Results

With the well-planned and rational wildlife management in Warmia and Mazury, the region is rich in big game. The dominant species is the wild boar[1], but the share of the two other species of big game in the total consumption of game meat is also large (Table 1). Thus, there are at least two reasons why it is advisable to carry out analyses of game meat towards the presence of xenobiotics: identification of contamination of natural environment and health of potential consumers.

The tissues and organs of red deer analyzed in the present study originated from 12 regions of the province

[1] The EU has not been importing wild boar carcasses from Poland for the past seven years; all wild boars hunted in Polish forests are processed and consumed in the country. In Poland, elk have been under all-year species protection for several years.

Table 2. Radioactivity (Bq/kg dry mass) of the potential food of red deer in Warmia and Mazury in autumn and winter 2000 (October, November, December – mixed samples) and in spring 2001 (single species samples).

Sample no.	Composition	Radiocesium (Bq/kg dry mass)			
		Pisz	Łężany	Olsztynek	Zaporowo
1	A	69.81±4.19*	9.65±0.96	31.09±1.36	37.42±3.74
2	A	42.16±3.22	2.41±2.20	20.23±3.92	28.34±1.73
3	A	10.38±1.59	1.72±1.11	16.09±1.68	22.43±1.82
4	B_1	3.13±0.69	1.36±1.36	2.87±2.00	4.07±1.33
5	B_2	2.05±1.16	2.19±1.42	1.64±1.06	3.12±0.90

* - counting error for the ^{137}Cs <10% at 1.64σ

Sample A composition (%): pine – new shoots + bark (11.20); bilberry (8.11); spruce -bark (4.00); birch (7.35); heather (6.24); oak (4.37); willow (3.90); raspberry (4.57); poplar (4.53); rape (5.43); jerusalem artichoke -tubers (4.00); grasses (16.00); fodder cabagge(1.00); acorns (1.00); beechwood -nuts (0.50); others – ferns, fungi, moss, sedge, maple, hornbeam, app tree, lilac, potato, lupine, hazel (17.80).

Sample B_1 composition (%): winter rape (100).

Sample B_2 composition (%): winter cereals (50); pasture grasses (50).

of Warmia and Mazury and from two regions in the western part of Russia (Fig. 2). The results of the analyses conducted on potential plant food and red deer tissues are shown in Table 2 and in Figs. 3-5, respectively. These data show that the concentration of ^{137}Cs in the tissues and organs of the red deer (*Cervus elaphus*) specimens obtained in Warmia and Mazury in 2000-01 was low but highly varied. It was noticed that in comparison to cattle (1-7 Bq/kg fresh mass in the province), the tissues of red deer contained considerably elevated concentrations of cesium only in areas around three towns and villages: Zaporowo, Olsztynek and Pisz (Fig. 3). Let us recall that the EU norms set permissible levels of total radioactivity at 600 Bq/kg for meat traded and sold on the market. All the analysed tissues and organs of the red deer obtained in Warmia and Mazury comply with this norm.

Fig. 4 depicts radioactivity expressed as an arithmetic mean for each particular tissue of bucks, does and calves (without discriminating between sexes). The highest radioactivity was determined in the tissues and organs of bucks.

No significant relationship was observed between the age of the shot deer and the levels of radioactive cesium in their carcasses. Large variation in the results presented

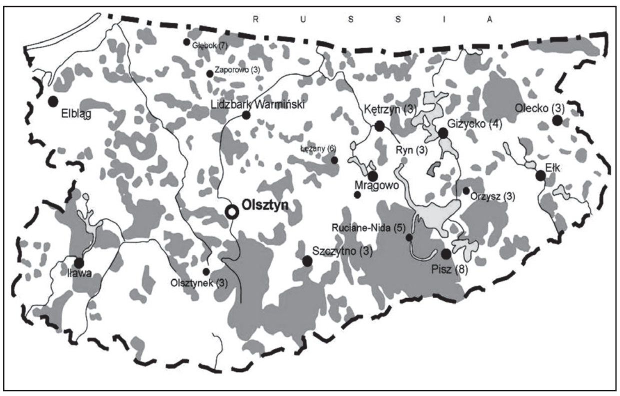

Fig. 2. Map of Warmia and Mazury showing areas where samples of red deers were collected.

in Fig. 5 depended on the site where the animals came from and the number of individuals tested rather than their age. For instance, a total of seven five-year-old deer were obtained, including 5 bulls and only two does. The group of two-year-old animals looked very much alike. As a consequence, the very high radioactivity of tissues determined in these two age categories (2 and 5 years of age) was in 70% attributed to the results obtained on the bucks' carcasses.

Discussion

The catastrophic accident at the Chernobyl nuclear power plant was feared to have caused acute health problems and long-term environmental consequences. The Chernobyl disaster was comparable in size only to the explosion of nitrogen and ammonium oxides in Chelyabinsk in September 1957, when an area of 20,000 km^2 was contaminated with radionuclides (^{134}Cs, ^{137}Cs, ^{90}Sr). Some intensive research on radioactive contamination in Poland has been conducted since 1986 [12-16]. The results of a preliminary study in northeastern Poland has shown that the annual intake of ^{137}Cs was highest in the first year after the Chernobyl explosion, reaching up to 4.8 determined by dietary analysis or 8.0 kBq according to determinations on foodstuffs. The annual intake in the second year was over three-fold lower than in the first year. In the third year, the drop in the intake was much smaller [11].

The investigations carried out by the Central Laboratory for Radiological Protection allowed researchers to estimate the value of an annual effective dose equivalent caused by radiation of artificially-made radionuclides per person in Poland, which in 1996 was 0.033 mSv [17].

Unlike people, who were able to take action in order to protect themselves against the effects of ionizing radiation, wild animals were defenceless. The range of β-radiation emitted by ^{137}Cs and ^{134}Cs in animal tissues is wide. This is due to the high energy of β-electrons: 1.176 MeV for ^{137}Cs and 2.056 MeV for ^{134}Cs. The question wheth-

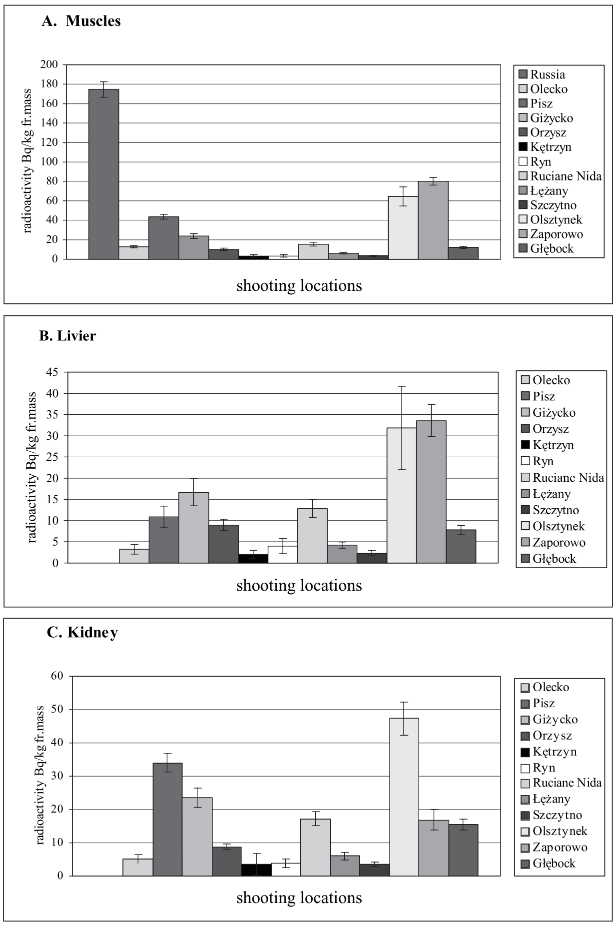

Fig. 3. Mean radiocesium in tissues of red deer for different shooting locations (± - counting error at 1.64 σ).

er or not long-term exposure to the radiation emitted by these two cesium nuclides as well as the short-term but intense radiation by ^{131}I after the Chernobyl accident have caused negative effects on the metabolism and DNA composition (mutations) of wild animals is not an easy one to answer [18]. The investigation completed by Głażejewski *et al.* [19] at the Polish Academy of Sciences in Popielno has revealed the incidence of abnormal (mutated) spermatozoa, namely spermatozoa with knobbed acrosomes, in the sperm of red deer from the Bieszczady Mountains (southeastern Poland). Has this been caused by radiation? This problem is extremely difficult to solve because no such research on deer was conducted in Poland between 1986 and 1990. Noteworthy is the fact that similar observations have been made in the USA for other animal species [20].

The results presented in Fig. 4 show that the tissues from bucks are much more radioactive than those from the tissues of does or calves. This is perfectly natural, because does are able to remove part of the xenobiotics present in their bodies at parturition. Furthermore, the behaviour of male deer is different. Apart from the adolescent age, they live in separate groups composed of individuals similar in age. They spend little time grazing during the rutting period, that is in September and early October. Afterwards, they graze, spending most of the time in woods. In spring, after shedding antlers, bucks return to live in forests for about 2 to 3 months. As a result, the share of foodstuffs from forest habitats in the diet of buck deer is much larger than that in the diets of does or calves. This means that bucks take in much more radioactive cesium.

Once it is released into the environment, radiactive ^{137}Cs may reach internal organs and tissues of red deer via different processes. The highest quantities of the radionuclide are ingested with food, much smaller amounts are taken up with water or from the air in the process of respiration. After the first year following the Chernobyl catastrophe, animals may have taken up considerable amounts of radionuclides when licking their skin. Sixteen years after the accident, we had to exlude this possibility from our analysis of the results presented in this paper, as no individual from the population living then was available for determinations (Fig. 5). Currently, however, the uptake of radiocesium by red deer depends mainly on the solid foodstuffs the animals ingest in forest. In Europe, the presence of red deer is associated with forest habitats. The species dwells in deciduous, mixed or uniform conrniferous forests. What all the habitats favoured by red deer have in common is that they either contain or are adjacent to grassy areas (meadows, pastures). Red deer are also characterized by seasonal changes in their choice of habitats [21]. In order to account for the relatively high radioactivity of tissues from the red deer specimens shot in the forest divisions of Zaporowo, Olsztynek and Pisz

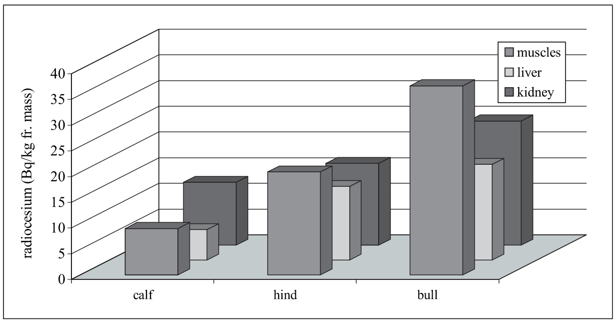

Fig. 4. Radiocesium of some tissues and organs of red deer in Warmia and Mazury (2000-01).

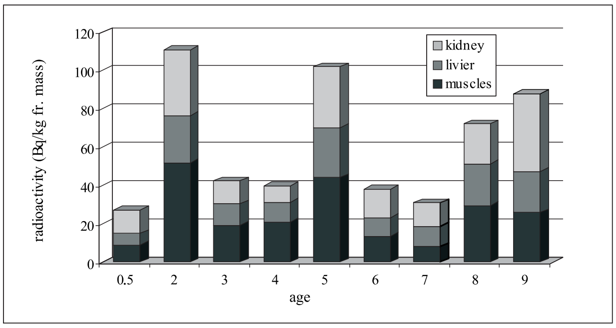

Fig. 5. Relation between age and ^{137}Cs radioactivity in some tisues and organs of red deer.

in comparison to those from other parts of the province, samples of plants readily eaten by red deer were collected from these sites and to determine their radioactivity. The choice of plants and their percent contribution in the animals' diets were based on the experiments by Janiszewski *et al*. [22, 23] carried out in the province of Warmia and Mazury in the previous year.

The analysis of the data presented in Table 2 and Figs. 3 and 4 shows some agreement between the land contamination and levels of radiocesium in red deer tissues. Also, radiocesium concentrations in the plant samples collected from the forests was in agreement with the behaviour and radioactivity of tissues of buck red deer.

The question of how different tissues and organs of animals tend to absorb and accumulate cesium is a slightly different problem. In the first months of investigations on wild animals after the Chernobyl accident it appeared that due to their feeding preferences and metabolism, roe deer were the species which suffered the highest levels of radiocesium pollution [25]. In contrast to heavy metals [24], cesium is mainly accumulated in muscles. The concentration of cesium in livers or kidneys is generally 2-fold lower (Figs. 3A, 3B, 3C) [1].

In recapitulation, at present the contamination with ^{137}Cs in northeastern Poland is not very high, which was made evident by the low values of radioactivity of the tissues of red deer determined in this study. However, radiocesium contamination is not even, and there are sites where ^{137}Cs radioactivity exceeds 100 Bq/kg fresh tissue.

Acknowledgements

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