

RADIOCAESIUM IN POLISH GAME MEAT

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Abstract

Current levels of radiocaesium in game were determined. Samples were taken in 10 regions and measured for their ^{137}Cs and ^{134}Cs activity concentrations. ^{137}Cs was found at measurable levels in the samples analysed. ^{134}Cs activity concentrations were negligible (below minimum detectable activity – MDA). The ^{137}Cs activity concentrations were very variable between and among the animal species even in the same region and ranged from MDA values to some tens of Bq/kg. An effective dose received by the most exposed populations was assessed.

Key words: radiocaesium, contamination, game animals, meat.

During the Chernobyl nuclear accident, up to 3.8×10^{16} Bq of radioactive caesium was released to the atmosphere. The ^{137}Cs : ^{134}Cs ratio was about 2:1 at that time (4). In Poland, the most contaminated areas were the Kluczbork vicinity (Opole Region) and some parts of the Kłodzko Valley (Wrocław Region) (7). At present, ^{137}Cs with a half-life of about 30 years is regarded as the most important artificial gamma-emitter in the environment. It causes longer-term exposures through the ingestion pathway and through external exposure from its deposition on the ground.

In many foodstuffs in the early years after this event, an increased level of radiocaesium was noted. The radiocaesium levels remained high in products such as game meat, mushrooms and berries. It is postulated that transfer of radiocaesium from soil via plants and mushrooms to animals is much higher in the forest ecosystems than in agricultural environments, and the radionuclide decrease is very slow (16-18, 25).

Generally, the consumption of game meat in Poland is low, but in some groups like hunters and poachers with their families this sort of foodstuffs can contribute significant quantities of meat to a diet. According to the data of Polish Hunting Association, more than 100 000 members were registered in 2007 (2). So, in about 400 000 people, game meat consumption can increase a total radiocaesium intake.

After the Chernobyl accident, Poland and other European countries initiated regular measurements of radiocaesium activities in various matrices (12). According to the law in force, samples of game meat (wild boar, red deer and roe deer) are regularly tested for their ^{137}Cs and ^{134}Cs activity concentrations. It is also important from an economic point of view, because Polish game meat is exported to many countries and must be checked for compliance with regulations.

The aim of the present study was to determine the current levels of radiocaesium in game animals hunted in Poland, and to estimate an effective dose from consuming domestic game meat.

Material and Methods

Sampling. Samples were taken at game meat processing facilities by veterinary inspection officers during 2007. Meat samples were then transported to appropriate Regional Veterinary Inspection Laboratories for analyses.

There were obtained 103 samples in total. The samples originated from 10 regions, but only from five of them all the species of interest were tested (details in Table 1 and Fig. 1).

Table 1

Numbers of animals sampled in the regions of Poland

Region	Sample number			
	wild boar	red deer	roe deer	total
Białystok	7	2	3	12
Bydgoszcz	3	3	3	9
Lublin	5	3	–	8
Olsztyn	4	5	3	12
Opole	4	3	4	11
Poznań	5	6	1	12
Szczecin	12	–	–	12
Wrocław	–	9	4	13
Gorzów Wielkopolski	–	5	7	12
Rzeszów	1	–	1	2
total	41	36	26	103

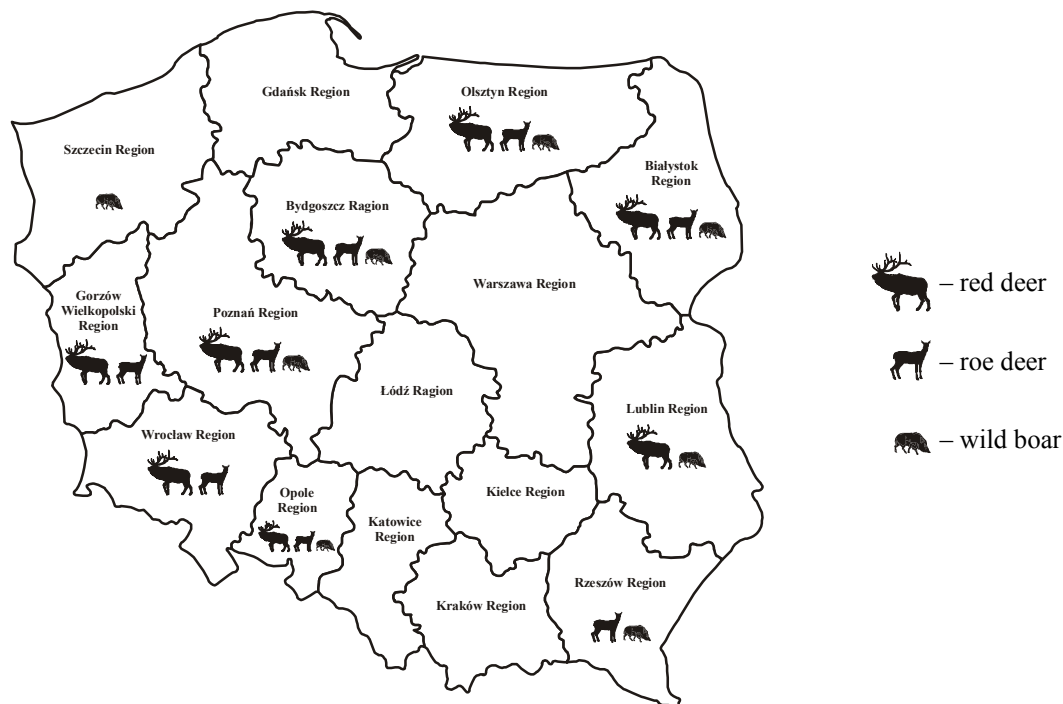


Fig. 1. Game species sampled in the regions of Poland.

Sample preparation. Muscles were grinded, weighed, and placed in 450 cm³ beakers of the Marinelli geometry.

¹³⁴Cs and ¹³⁷Cs measurements. ¹³⁷Cs and ¹³⁴Cs activity concentrations were determined by gamma-ray spectrometry using scintillation (NaI/Tl) detectors fixed in lead shields. Counting time was set to 72,000 s. Radionuclide identification and calculations were carried out with the Genie 2000 software (Canberra).

All the laboratories work with established internal quality assurance procedures, and participate in intercomparison studies.

Radiation dose assessment. For ¹³⁷Cs, a dose conversion factor of 1.3×10⁻⁸ Sv/Bq was used to estimate the effective dose received by individuals consuming game meat (3). This dose was calculated by means of the relation:

$$H_E = A_k m D_{kf(k)}$$

where H_E is the effective dose (Sv); A_k – the concentration of k radionuclide (Bq/kg); m – the quantity of consumed meat (kg) and $D_{kf(k)}$ is the dose conversion factor for k radionuclide (26).

Results

Radiocaesium activity concentrations. The ¹³⁴Cs activity concentrations were negligible (below MDA) in all the samples analysed.

Generally, the radiocaesium concentrations were very variable between and among the animal species even in the same region ranged from MDA values to some tens Bq/kg. The activity concentrations of ¹³⁷Cs in

game meat are given in Figs 2–4. The results are expressed on a fresh weight basis. The highest ¹³⁷Cs concentration levels were found in the wild boar meat samples from the Poznań Region. In one wild boar meat sample, the ¹³⁷Cs activity concentration exceeded 120 Bq/kg. Only in wild boar meat, the mean activity concentration of ¹³⁷Cs was higher than 10 Bq/kg (Table 2).

Table 2

Mean ¹³⁷Cs activity concentrations in game meat

Species	Mean activity concentration (Bq/kg)
wild boar	14.40
red deer	8.74
roe deer	6.34
combined	9.83

Radiation dose assessment. Mean effective doses from consuming 1 kg of game meat are presented in Table 3. The highest mean effective dose was calculated for wild boar meat. For the wild boar sample with the ¹³⁷Cs activity concentration exceeded 120 Bq/kg, the effective dose was calculated to be 1.62 μSv per kg.

Table 3

Mean effective doses from consuming 1 kg of game meat

Species	H_E per kg of game meat (μSv)
wild boar	0.19
red deer	0.11
roe deer	0.08
combined	0.13

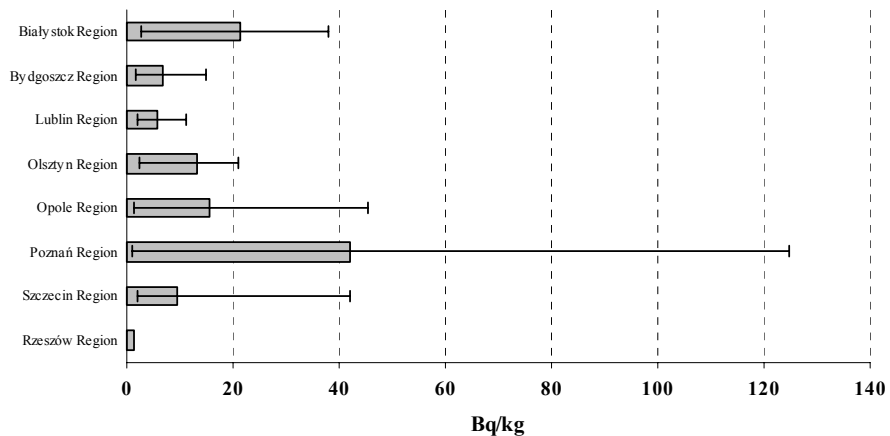


Fig. 2. Activity concentrations of ^{137}Cs in meat of wild boar from the regions of Poland (mean and range).

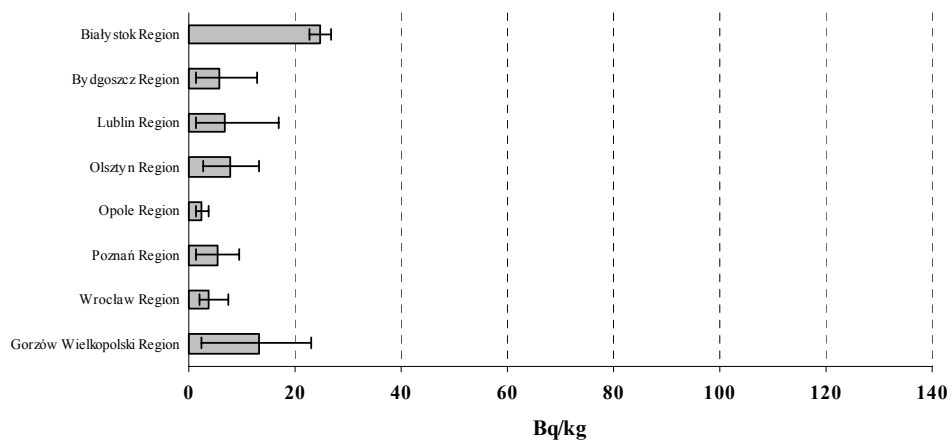


Fig. 3. Activity concentrations of ^{137}Cs in meat of red deer from the regions of Poland (mean and range).

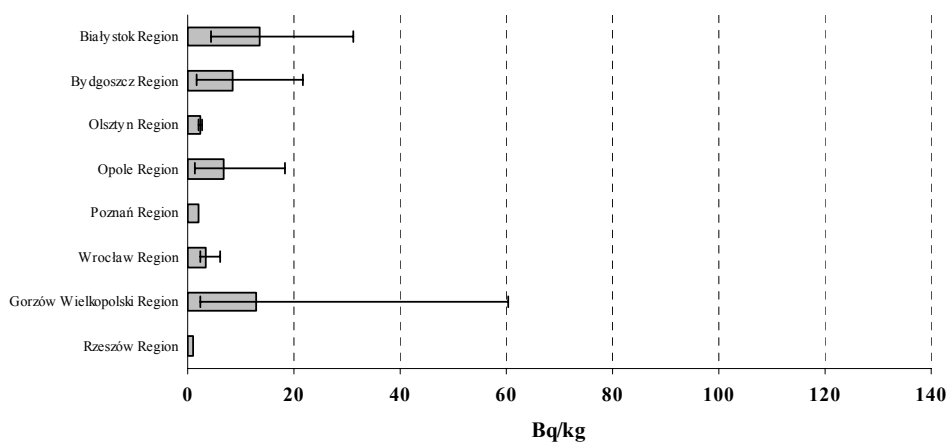


Fig. 4. Activity concentrations of ^{137}Cs in meat of roe deer from the regions of Poland (mean and range).

Discussion

Due to a relatively short physical half-life (2 years) and a lower deposition of ^{134}Cs after the Chernobyl accident (7), the activity concentrations of this radionuclide in game are negligible, and its contribution to an effective dose received by game consumers could be omitted.

In the case of ^{137}Cs , the ecological half-life of this radionuclide in the forest soil is about 20 years and of the same order of magnitude as its physical half-life (23). So, in some areas ^{137}Cs could be at high levels even nowadays. In Poland after the Chernobyl accident, the highest ^{137}Cs activity concentration (227 Bq/kg – mean, 4–4357 Bq/kg – range) was observed in roe deer followed by red deer and wild boar. During the next five years, radiocaesium activity concentrations steadily decreased to some tens Bq/kg (12). In our study, the measured activity concentration values were even lower. Similarly to Austrian findings, in recent years the average ^{137}Cs activity concentration in Poland has been higher in meat from wild boar than that in meat from roe deer or red deer (25).

There is significant variation in the ^{137}Cs activity concentrations between and among game animal species. It could be attributed to different contamination levels even in neighbouring areas and different feeding habits of game animals (26).

Extreme environmental conditions, including low soil pH-values, high amounts of soil organic carbon, high precipitation, favour the transfer of deposited radiocaesium from soil to forest vegetation (10). Therefore, game animals consuming forest feedstuffs can absorb radiocaesium at higher quantities in comparison with food producing animals fed with agricultural fodder.

It is well documented that some mushrooms, readily consumed by animals, show high ability to accumulate radiocaesium (6, 12, 19–21). Bay bolete (*Xerocomus badius*), one of the most wide-spread mushroom species in Poland, reveals a unique radiocaesium accumulation feature. Aumann *et al.* (5) found that pigments from the bay bolete cap cuticle (badiion A and norbadiion A) can complex potassium and its chemical analog caesium. Moreover, deer truffle (*Elaphomyces granulatus*), which also contains particularly high levels of radiocaesium, could be another radionuclide source for game animals (14, 22). The Latin, English, German, and Polish names of this mushroom species indicate that it could be eaten by red deer and roe deer. In the years 1997–2003 Putyrskaya *et al.* (22) measured about 200 samples of wild boar from the state forestry Bad Waldsee (Germany) for their ^{137}Cs activity concentrations. The muscle radiocaesium levels varied widely from less than 5 to more than 8 000 Bq/kg (fw). The investigators observed maximum values of ^{137}Cs activity concentrations during the winter period. They connected this pronounced maximum with the consumption of highly contaminated deer truffles, which were available for wild boar in winter. These mushrooms grow in a depth of 6–8 cm in spruce forest

soil, which corresponds to O_h/A_h (organic layer/mineral layer) horizon where the peak of ^{137}Cs activity is still observed (21, 22). Hohmann and Huckschlag (15) studied a wild boar stomach content to test the influence of *Elaphomyces granulatus* intake on wild boar radiocaesium contamination. They found deer truffles in significantly higher proportions in stomachs with maximum contamination levels. Moreover, animals consuming deer truffles could digest contaminated soil components.

Red deer and roe deer, as ruminants, eat mainly vascular plants. The animal diet depends on local plant availability. Moreover, there are some seasonal variations in the diet composition (8, 9, 11). In addition, the consumption of pine (*Pinus silvestris*) bark is a common phenomenon, especially in winter (11). Generally, the radiocaesium concentrations in vascular plants are considerably lower than those in mushrooms (21, 27). However, Zibold *et al.* (27) found the higher aggregated transfer factor T_{ag} soil-plant of ^{137}Cs for fern (*Dryopteris carthusiana*). It is a common species in Polish forests. Recently, even an increase in the fern occurrence number or specimen abundance has been observed (1). Thus, an increasing fern contribution to the total ruminants' diet can elevate the intake of radiocaesium by animals.

The effective dose, which residents in Poland receive from consuming game meat, could be considered very low with the exception of hunters and poachers with their families. There are no data on the annual game meat consumption per capita in Poland. In Finland and Austria the average game intake amounts to 0.6 and 1.2 kg/a, respectively (18, 25). In a Swiss study an average of 2.2 wild game meals per week (18 kg/a) was found representative for hunters' families during the hunting season (13). Assuming the mean annual game consumption of 20 kg/a and the mean effective dose of 0.13 μSv per kg, an individual in the most exposed populations could receive the effective dose of 2.6 μSv . Taking into account the annual public dose limit (1 mSv), consumption of local game meat is safe in terms of radiological protection.

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