# Evolution of the contamination rate in game

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**Abstract**

The Chernobyl accident caused considerable contamination of natural environments in large parts of Europe. In the most heavily contaminated areas close to the reactor site tissues from two wild animal species (wild boar, *Sus scrofa* and roe deer, *Capreolus capreolus* [L]) have been sampled for determination of radioactive contamination. The level of $^{137}Cs$ has been determined in a large number of samples and other radionuclides like $^{90}Sr$ in some samples. Systematic samplings during different seasons of the year have been made of these two species within the framework of the ECP9 project. The results show that there is a considerable individual variation within each season for both these species and also a seasonal variation most pronounced in wild boar. For the wild boar the minimum levels of $^{137}Cs$ are seen during summer (end of August) and autumn (end of October) and maximum levels in winter (end of February). In the roe deer the maximum levels are seen in spring (end of May) and minimum in summer. These variations reflects the feed selection during different seasons of the year. The level of $^{137}Cs$ contamination in muscular tissue has not decreased noticeably during the study period from summer 1992 to winter 1995.

## Introduction

Environmental contamintion with radioactivity will cause intake of radioactivity by wild animals living in the contaminated area. Such contamintion of game was detected already in the first years of atmospheric nuclear bomb testing [for a review see 1]. Studies performed in that period also showed a seasonal variation caused by the differences in forage selection at different seasons of the year. Systematic studies of game in a heavily contaminated environment seems, however, not to have been done earlier.

The objectives of the present study were to study contamination levels in muscular tissue of roe deer (*Capreolus capreolus* [L.]) and wild boars (*Sus scrofa*) and to evaluate the importance of meat from wild animals as source of radioactive contaminants to humans. The results can be used to calculate radiation doses to humans consuming this type of food products. Data was also obtained on the radioecology of these animals and the importance of different forage plants used by the animals during different periods of the year.

## Material and methods

Sampling of roe deer and wild boars were performed in three areas heavily contaminated by the Chernobyl acident in Ukraine, Byelarus and Russia. The study was part of a larger project (ECP5 and ECP9) where transfer of radionuclides were studied in rural communities where people are living to a great extent on products produced in natural and semi-natural ecosystems.

Details of the three sampling areas are given below as well as the actual sampling periods.

**The research area in Ukraine**

The samples were all obtained from within the evacueted zone around the damaged nuclear power plant in Chernobyl. The area is charachterized by a mainly low flat relief with river flood-plains, terraces, end moraine ridges, moraine fluvioglacial and limnoglacial plains. Rather infertile sandy soils dominate the upper levels, where fallow arable lands occupies the major part. Grassland with *Elytrigia repens* (L.) Nevski, *Festuca ovina* L., *F. rubra* L., and *Oenothera biennis* L. is dominant. Planted forests with Scots pine (*Pinus sylvestris* L.) of various ages, sometimes with oak (*Quercus ruber* L.) in the understory occur in the upland sandy areas. *Alnus glutinosa* (L.) Baertn. dominates low-laing swamp forests. The lower level of the zone is occupied by the flood plains of the river Pripyat and its tributaries. The vegetation in these areas is dominated by *Salix acutifolia* Wells., xerophytic shrubs and graminids.

During this study totally eleven sampling were made in the Chernobyl area. The first sampling was in early June 1992 and after that samplings have been made in mid-August (summer), late October (autumn) and end of February beginning of March (winter).

Samples have been obtained in two areas with different contamination levels. The surface contamination $^{137}Cs$ in the high contamination area is 1100 to 1500 kBq per $m^2$ and in the low contaminated area 180 to 700 kBq per $m^2$.

Stomach content from the wild boars and rumen content from the roe deer, faeces, forelimb flexor muscles, liver and one metacarpal bone, but also other tissues, were sampled and deep frozen for future analyses. The stomach/rumen samples are preserved by mixing with an equal volume of 95 % ethanol. After a rapid field check of the stomach/rumen content about 100 g (wet weight) of plant species occuring in noticable quantities are collected around the point where the animal is sacrifized.

**Animal sampling**

Most animals were collected during early mornings or during afternoons and nights. Efforts were made to obtain undisturbed specimens. Only during the winter period with snow, when animals were hiding in thick cover, a certain amount of beating was executed.

Animal tissue samples were measured for $^{137}Cs$ in a $\gamma$-spectrometer system (Ortec) with a GeLi detector. The system has been intercalibrated and corresponds to established requirements. The results are expressed in Bq per kg fresh weight .

For quantitative botanical analysis of stomach/rumen samples the technique described by Eriksson et al. [2] was used. Briefly the methods utilises ethanol preserved material which is stirred in a bucket and 400 to 500 ml is washed through a set of sieves with mesh sizes ranging from 4000 to 500 $\mu$m. Particles smaller than 500 $\mu$m are discarded. Each fraction is put on a transparent tray and the plant fragments to be examined are indicated by an underlaing 100 point grid. The area frequency of plants/plant groups is converted to frequency by weight using weight constants specific for the plant groups and particle sizes found.

A subsample of the preserved stomach/rumen samples was freeze dried and the $^{137}Cs$ content was determined. The dried material was then ashed at 600°C over night in a muffle furnace to determine the ash content of the stomach/rumen content.

**Plant sampling**

About 100 g (wet weight) of plant material was collected in the immediate vicinity of the spot where the animal was sacrifized using the initial field check to identify the plant species last grazed by the animal. The plant material is dried and ground to a powder wich is measured in the $\gamma$-spectrometer. The radioactivity was also determined in 5 cm soil samples taken on the location of animal sampling.

**The research area in Belarus**

The sampling was performed near the villages Savichi and Dvor-Savichi in the evacuted zone just north of Chernobyl. The geographical charachteristics are similar to the Ukrainian sampling site. The level of $^{137}Cs$ contamination is 555 to 1480 kBq $^{137}Cs$ per $m^2$.

Samplings were performed in the selected area during February, winter sampling, and during July, summer sampling, 1994 and 1995. In February roe deer and wild boars were obtained as well as moose (*Alces alces* [L.]) and during the July sampling only wild boars. Different tissues from the animals and contents from the gastro-intestinal tract were taken for determination of $^{137}Cs$ and $^{90}Sr$. Rumen/stomach content was also sampled in 1994 for determination of botanical composition using the same method as in Ukraine [2]. The plant species identified were measured for radioactivity content and the results were used to calculate the daily intake of radionuclides by the animals.

**The research area in Russia**

During August 1995 a wild animal sampling expedition was performed in the Novozybkov area within the ECP9 programme. Wild animal, roe deer and wild boar, samplings had earlier been performed during the period October to December in 1992, 1993 and 1994.

The samplings were done in an abandoned area with a $^{137}Cs$ surface contamination of 1.25 to 10 x $10^5 Bq/m^2$.

**Results and discussion**

UKRAINE

The number of animals and the $^{137}Cs$ levels in muscular tissue are shown in Figure 1 (wild boar) and Figure 2 (roe deer) for the entire study period. As can be seen from thesa figures the results show a considerable seasonal variation for both species. For the wild boar the lowest values are seen during summer and autumn, while roe deer have the lowest levels in winter. There is a considerable variation in radiocesium levels in animals of the same species obtained from the same area. But roe deer obtained from a specific area generally have lower contamintion levels than wild boars obtained from the same area. This variation is also seen in the contamination of the dried and ashed rumen/stomach samples due to the differences in individual forage selection seen in free ranging wild animals. This seasonal variability in $^{137}Cs$ contamination has earlier been reported in free ranging ruminants (e.g. [3, 4]) from other parts of Europe after the Chernobyl accident.

The mean ash content in stomach samples from wild boars varies from 32 % d.m. (dry matter) content in the winter to 6 % of d.m. in the summer and with intermediate values, mean 14 %, in the spring and autumn. But also here the individual variation is considerable. In the roe deer the seasonal differences are smaller with ash contents of 9 to 15 % d.m. for spring and winter, respectively.

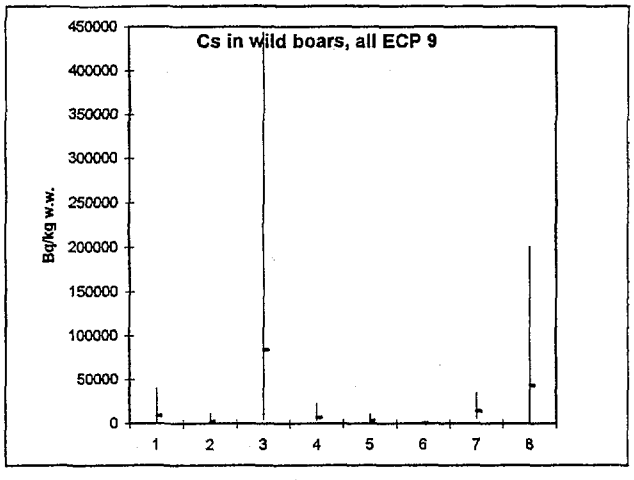


**Figure 1.** The contamination of muscular tissue (range and median) from wild boars (*Sus scrofa*) sampled from 1992 to 1994 in the Chernobyl zone. The figures on the abscissa denotes the sampling periods and number of animals sampled (n). 1 summer 1992 (n=5), 2 autumn 1992 (n=7), 3 winter 1993 (n=11), 4 spring 1993 (n=8), 5 summer 1993 (n=6), 6 autumn 1993 (n=4), 7 winter 1994 (n=6) and 8 spring 1994 (n=7).

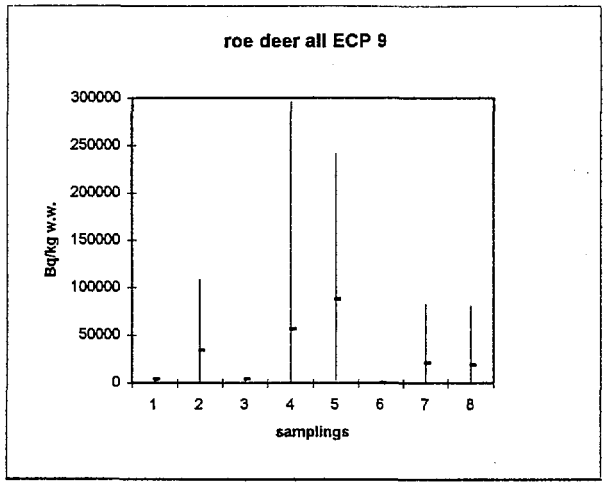


**Figure 2.** The contamination of muscular tissue (range and median) from roe deer (*Capreolus capreolus* [L.]) sampled from 1992 to 1995 in the Chernobyl zone. The figures on the abscissa denotes the sampling periods and number of animals sampled (n). 1 summer 1992 (n=5), 2 autumn 1992 (n=6), 3 winter 1993 (n=6), 4 spring 1993 (n=6), 5 summer 1993 (n=6), 6 autumn 1993 (n=6), 7 winter 1994 (n=6) and 8 spring 1994 (n=6).

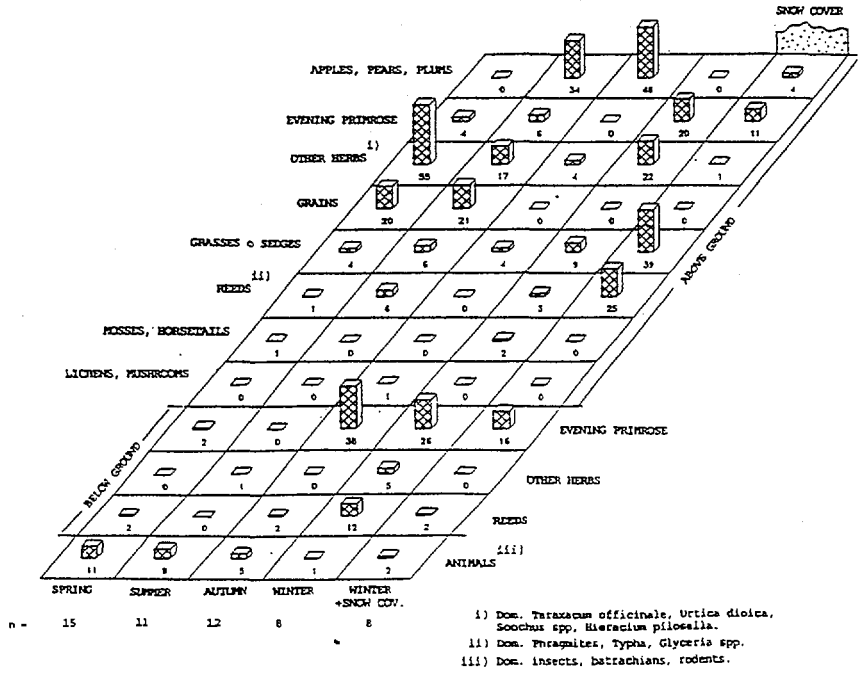


**Figure 3.** Mean results of quantitative botanical analysis of stomach content from wild boars obtained during the different seasons in the Chernobyl zone.

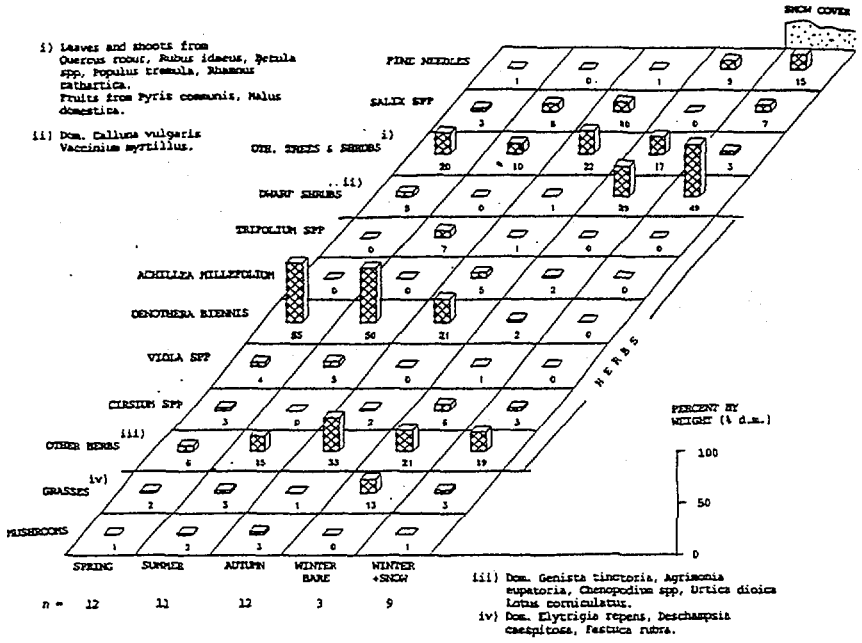


**Figure 4.** Mean results of quantitative botanical analysis of rumen content from roe deer obtained during the different seasons in the Chernobyl zone.

Although the intake of $^{137}Cs$ with soil is considerable the uptake from the gastro-intestinal tract is expected to be limited in from soils high in organic matter [5]. A certain part of the measured contamination of the muscular tissue must, however, come from ingested soil both in the most contaminated wild boars and roe deer as it is diffcult to account for these levels (> 0.2 MBq/kg tissue w.w) with the contamination levels found in forage plants eaten by the animals.

Table 1. Concentration of $^{137}Cs$ and $^{90}Sr$ in tissue samples from ungulates sampled in the Dvor Savichi area in Byelarus during February, 1994 and 1995.

| Animal species | Sampling year | Animal age, years | $^{137}Cs$ in muscle kBq/kg wet weight | $^{90}Sr$ in muscle kBq/kg dry matter | $^{90}Sr$ in bone |
|---|---|---|---|---|---|
| Moose | 1994 | 4 | 7.03 | 0.004 | 29.63 |
| (*Alces alces*) | 1995 | 1 | 0.19 | – | 11.42 |
| | " | 6 | 11.7 | 0.029 | 35.99 |
| | " | 5 | 4.35 | 0.095 | 95.10 |
| Roe deer | 1994 | 1 | 6.29 | 0.023 | 61.30 |
| (*Capreolus* | " | 2 | 10.73 | 0.012 | 5.13 |
| *capreolus*) | 1995 | 5 | 4.84 | 0.004 | 4.57 |
| | " | 5 | 3.67 | -- | 4.25 |
| | " | 2 | 4.21 | 0.020 | 5.63 |
| Wild boar | 1994 | 5 | 3.70 | 0.008 | 4.56 |
| (*Sus scrofa* | " | 3 | 40.70 | 0.005 | 9.15 |
| [L]) | " | 5 | 4.44 | 0.010 | 4.21 |
| | 1995 | 3 | 17.3 | 0.005 | 30.88 |
| | " | 2 | 8.40 | 0.003 | 9.64 |
| | " | 0.8 | 61.90 | -- | 11.31 |

BELARUS

The measured concentrations of $^{137}Cs$ and $^{90}Sr$ are shown in Table 1 for the winter sampling of moose (*Alces alces*), roe deer and wild boar. Both in July 1994 and 1995 three wild boars were obtained in this study area. In 1994 the $^{137}Cs$ contamination of muscular tissue was from 0.3 to 15.5 kBq/kg w.w. and in 1995 from 8.4 to 19.8 kBq/kg w.w. Both in winter and in summer the contamination levels vary considerably for the wild boars although the levels appear lower in summer than in the winter like in Ukraine. The roe deer sampled in winter showed more comparable levels of contamination due to feeding on plants with a more even level of $^{137}Cs$ contamination.

The quantitative botanical analysis of rumen/stomach samples showed that young top sprouts of aspen and willow made up 60 to 75 % of the feed intake of these animals. Other tree species (e.g. birch, Scots pine, oak and apple) and shrubs constituted another 20 to 25 % of the ration (see Table 2). During the winter the diet of wild boars was dominated by lower and under ground parts of a few plant species while the diet of the ruminats contained components from several plant species. During the summer the three wild boars sampled had an even more one-sided diet with a mean content of 95 % oats grain, maize and potatoes. The remainder was other parts of oat straw and grasses.

Table 2. Botanical composition of rumen/stomach content from ungulates sampled in the Dvor-Savichi area in February, 1994.

| Animal species | Amount % | Plant species |
|---|---|---|
| Moose | 40 | Young sprouts and bark of aspen |
| | 35 | Young sprouts and bark of willow |
| | 15 | Young sprouts and bark of birch |
| | 10 | Young bark of Scots pine |
| Roe deer | 30 | Bark of aspen |
| | 30 | Young sprouts of willow |
| | 21 | Young sprouts of different trees (e.g. birch, apple, oak) and shrubs |
| | 12 | Young sprouts of bilberry |
| | 3.5 | Young sprouts of raspberry |
| | 3.5 | Young sprouts of cowberry |
| Wild boar | 90 | Roots, rhizomes, lower parts of marsh plants |
| | 5 | Tissues of animals (moose, wild boar, roe deer, hare) |
| | 2 | Rodents (mice, voles, shrews) |
| | 1 | Earthe worms, larvae |
| | 2 | Soil |

Table 3. $^{137}Cs$ contamination (kBq/kg w. w.) of forage plants selected by wild animals in the Dvor-Savichi area.

| Plant parts and species | $^{137}Cs$, kBq/kg fresh weight | |
|---|---|---|
| Young sprouts of aspen (*Populus tremula*) | 1.54 | |
| Bark of aspen | 7.19 | |
| Young sprouts and bark of willow (*Salix* spp.) | | 1.06 |
| Young sprouts of birch (*Betula* spp.) | | 2.15 |
| Apple tree (*Malus dom.*) | | 2.32 |
| Young sprouts and bark of pear (*Pyrus comm.*) | | 2.57 |
| Young sprouts of billberry (*Vaccinium myrtillus*) | | 2.03 |
| Young sprouts of raspeberry (*Rubus ideus*) | 4.30 | |
| Raspberries | | 3.01 |
| Bark from Scots pine (*Pinus sylvestris*) | 4.14 | |
| Cough-grass (*Agropyron repens*) | | 0.37 |
| *Oenothera biennis* | | 0.99 |
| *Phragmites communis* | | 0.74 |
| *Genista tinctoria* | | 1.49 |
| *Melilotus alba* | 0.09 | |
| *Potentilla erecta* | | 5.48 |
| *Urtica dioica* | 0.32 | |
| *Chamaenerium* | 0.73 | |
| *Artemisa vulgaris* | | 0.07 |
| Animal tissues | 4.71 | |
| Rodents | | 0.97 |
| Earth worms, larvae | | 2.73 |
| Soil | | 3.07 |

The $^{137}Cs$ contamination of forage plants sampled in the Byelarussian study area where the wild animals were sampled in February is shown in Table 2.

The grain consumed by the wild boars during summer contained on average 13 Bq/kg fresh weight and the other feeds 25 Bq/kg fresh weight.

There is an obvious discrepancy between observed intake of contaminated plants and the measured levels of contamination in muscular tissue of the sampled ungulates. This is partly due to the fact that animals are moving between areas with different levels of contamination so the animal body is not in balance with the intake.

The $^{90}Sr$ contamination of muscular tissue is low compared to the levels found in bone (results not shown) which generally are more than two orders of magnitude higher. There is no dirct correlation between the measured levels in these two tissues most certainly due to the much faster turno over of Sr in soft tissue than in bone. There was not any correlation between the surface area contamination with $^{90}Sr$ and the levels in muscular tissue.

RUSSIA

A number of wild boars and roe deer have been sampled in the Novozybkov area in Russia from 1992 to 1994. The results are presented in Table 4. All these samples were obtained from October to December so no obvious seasonal change is seen. In these animals the forage intake was not studied but the aggregated transfer ($t_{(ag)}$, $m^2/kg$ muscular tissue w.w.) have been calculated both for the wild boars and the roe deer. The results from this area also show a considerable variation between different individuals as in the two other study areas. In all these cases this is an effect of the considerable variability in surface area contamination of radioactivity.

Table 4. Concentration of $^{137}Cs$ in muscular tissue samples from wild boars and roe deer sampled in the Novozybkov area mainly during the period October to December 1992, 1993 and 1994.

| Species | Sampling year | n | $t_{(ag)}$, $\cdot 10^{-3}$, range | $^{137}Cs$ kBq/kg in muscle, range | |
|---|---|---|---|---|---|
| Wild boar | 1992 | 7 | 1.37-7.89 | 1.24-7.10 | high contaminated area, |
| | 1993 | 12 | 0.39-6.50 | 0.25-3.40 | 8 - 10 $\cdot 10^5$ Bq per $m^2$ |
| | 1994 | 4 | 0.13-68.97 | 1.19-62.15 | -" |
| | 1992 | - | | – | low contaminated area |
| | 1993 | 4 | 0.85-3.42 | 0.17-0.69 | 1.25-2.5 $\cdot 10^5$ Bq per $m^2$ |
| | 1994 | - | | – | |
| Roe deer | 1992 | 5 | 6.56-9.03 | 5.90-8.13 | high contaminated area, |
| | 1993 | 9 | 1.27-18.45 | 1.14-10.6 | 8 - 10 $\cdot 10^5$ Bq per $m^2$ |
| | 1994 | 1 | 0.86 | 0.80 | -" |
| | 1992 | 2 | 6.73, 7.45 | 1.35, 1.49 | low contaminated area |
| | 1993 | 2 | 2.05, 2.60 | 0.41, 0.52 | 1.25-2.5 $\cdot 10^5$ Bq per $m^2$ |

## Conclusions

The results of both this study show a considerable seasonal variation in contamination levels of muscular tissue with $^{137}Cs$ with lower levels in the summer and autumn for the wild boar and lower levels in the winter for the roe deer. All Russian samples except one has been obtained during late autumn or early winter so possible seasonal changes can not be seen in these samples.

Generally the contamination level is lower in roe deer than in wild boars obtained from the same sampling area. But the individual variations within each species is considerable during all seasons especially in the Chernobyl material reflecting the great variability in surface area contamination.

There is no obvious decrease in the level of contamination of animal tissue samples obtained from the different study sites during the three years studied.

In the wild boarr the lowest contamination is seen during summer and autumn. These periods would be the best hunting periods to avoid intake of radiocesium from game by hunters and their families. In the roe deer the lowest contamination is seen during winter which hence would be the preferable hunting time to avoid human contamination with radiocesium.

Samples from the Byelorussian site have been analysed for $^{90}Sr$. The levels in muscular tissue are from 5 to 25 Bq/kg fresh weight and not correlated to the levels in bone or the level of surface contamination with $^{90}Sr$. The levels in bone are three orders of magnitude higher than in the soft tissue.

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