Bull. Environ. Contam. Toxicol. (1993) 51:633–639

Environmental Contamination and Toxicology

# $^{137}$Cesium and $^{134}$Cesium in Roe Deer from North and Middle Hesse (Germany) Subsequent to the Reactor Accident in Chernobyl

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Environmental contamination with radionuclides, heavy metals and chlorinated hydrocarbons is reflected by the concentration of these substances in the tissues of so-called "biological indicators," animals such as game and fish that are wholly dependent upon their environment and therefore display environmental contamination with xenobiotics. The extent and the temporal development of the xenobiotic burden to the environment and food chain can be monitored by measuring concentration of xenobiotics in muscle tissue of biological indicators (Brunn et al. 1985, Kreuzer and Hecht 1988a, 1988b, Rimkus and Wolf 1987, Schüler et al. 1985). The present report describes the contamination of muscle tissue from 396 roe-deer from north and middle Hesse (Germany) after the reactor accident in Chernobyl on April 26, 1986.

## MATERIALS AND METHODS

Muscle tissue from the thighs of 396 roe deer from north and middle Hesse was examined. The deer had been submitted for routine necropsy in 1986 (11 animals from June to December), 1987 (183), 1988 (130), 1989 (66) and 1990 (6). The tissue material was homogenized and placed into 1 l plastic bottles with 0.5% w/w benzoic acid added as preservative. The sample weight varied between 0.9 and 1.0 kg. Determination of $^{137}$Cs, $^{134}$Cs and $^{40}$K was performed using three energy and efficiency calibrated high-purity germanium detectors from Canberra-Packard, Frankfurt/M., Germany (21-24% relative counting gain using a 3-in x 3-in NaI detector as reference). IBM AT 02 computers and the software package SPECTRAN F, Ver. 2d1 from Canberra-Packard, Frankfurt/M., Germany, were used for calibration of the systems and for evaluation of the data. The mixed standards used for calibration of energy and efficiency were obtained from the Physikalisch-Technische Bundesanstalt (PTB), Brunswick, Germany. Energy calibration checks were made daily before measurements.

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The 1$\sigma$ error of the gamma activity measurements for $^{137}Cs$, $^{134}Cs$ and $^{40}K$ was <5% in all cases. The limit of detection was 0.2 Bq/kg with $^{60}Co$ as reference. Abbreviations: Bq Bequerel (1 disintegration /s)

## RESULTS AND DISCUSSION

Release of synthetic radionuclides into the biosphere took place in the 1960s, prior to the reactor accident in Chernobyl, as a result of above-ground nuclear weapons testing and erratic reactor technology. Some well-known examples are the incidents in 1957 in Windscale, England and in 1979 in Harrisburg, USA (Wiechen 1989). In contrast to these events in which deposition of a comparatively limited amount of radionuclides over a relatively small geographic area took place, the consequences of the reactor accident in Chernobyl on April 26, 1986 were much more extensive. Within a short time-span a large part of the reactor mass was released into the atmosphere (Myasoedov and Pavlotskaya 1989) and were spread over Europe by winds. As a consequence, contamination of an extensive geographical region occurred (Kreuzer and Hecht 1988a).

Quantitatively, the most-important nuclides released in this accident were $^{131}J$, $^{144}Ce$, $^{134}Cs$ and $^{137}Cs$ (Myasoedov and Pavlotskaya 1989). The half-life of $^{131}J$ is only 8.02 days, and that of $^{144}Ce$ 284 days. Consequently, a long-term contamination of the environment with these products can be ruled out. The half-life values of $^{134}Cs$ and $^{137}Cs$ are significantly longer; 2.06 and 30.2 years, respectively. Accordingly, they are transferred from the soil into the food chain, and can still be detected in German food-stuffs (Georgii et al. 1990).

Contamination of the food chain with radiocesium after the reactor accident is reflected by the cesium content in the roe-deer used as biological indicators. Figures 1 and 2 (Box and Whisker plots) demonstrate the temporal development of $^{134}Cs$ and $^{137}Cs$ contamination of muscle tissue in the deer from 1986 (June) to 1990.

By 1988 the $^{137}Cs$ concentrations had already returned to values that were approximately as low as had been measured before the reactor accident. These levels can be attributed to residual contamination from atmospheric testing of nuclear weapons (Kreuzer and Hecht 1988a). For the years 1989 and 1990 we found an average of only 3.8 and 2.1 Bq for $^{137}Cs$, respectively, per kg muscle tissue (median values). The corresponding arithmetic means were 9.2 and 2.1 Bq/kg, respectively.

Compared to 1986, maximum values of more than 700 Bq $^{137}Cs$ per kg muscle tissue were measured in 1987 (Fig.1). This finding may be the result of an increase in the tissue concentration of radiocesium in the

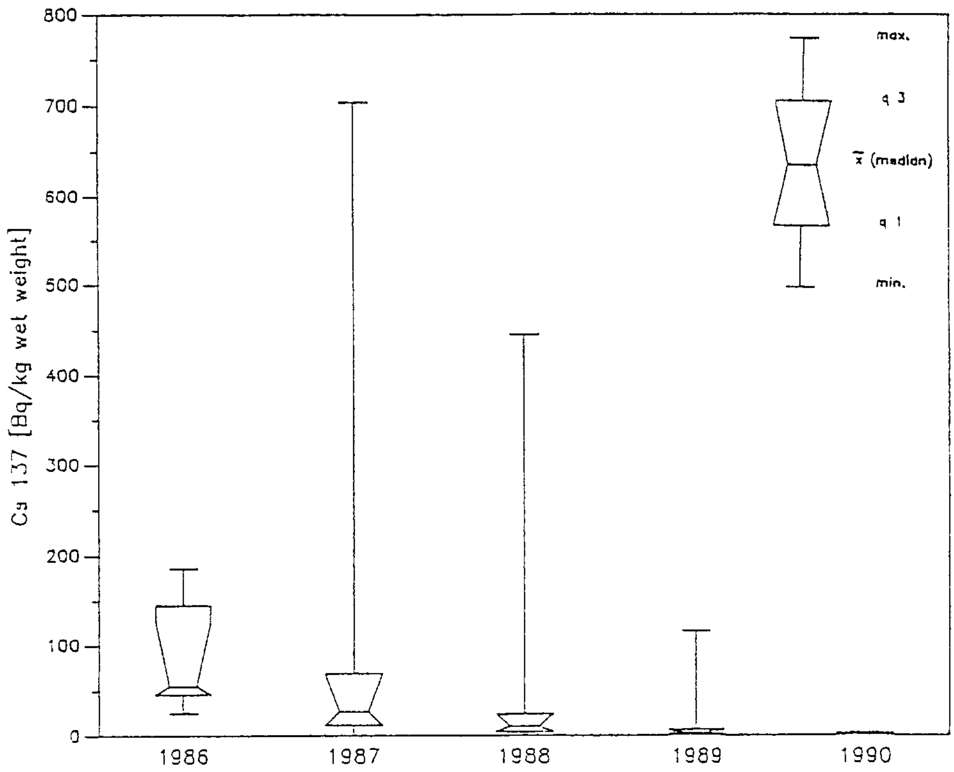


Figure 1. Temporal development of the $^{137}Cs$ contamination of muscle tissue in roe deer from 1986 - 1990.

autumn months (Fig. 3; corresponding values were determined for $^{134}Cs$, data not shown).This observation can be explained by the increase in cesium concentration of vegetation in the autumn. At this time of year, plants store increased amounts of minerals and nutrients for use in the coming period of intense spring growth.

Additionally, deer tend to feed more on perennial plants in the fall, and these in turn tend to show much higher cesium concentrations than do grasses after the second and third cutting (Kreuzer and Hecht 1988a, Langfristiges Meßprogramm des Landes Hessen zur Überwachung der Radioaktivität nach dem Reaktorunfall in Tschernobyl, 1988). Also, hunters know that deer are particularly fond of eating mushrooms in the fall. The fruiting bodies of mushrooms, which accumulate radiocesium, grow primarily in the late summer and autumn. In experiments with goats, radiocesium from mushrooms appeared to be biologically highly accessible (Hove et al. 1990). The rise in $^{134}Cs$ and $^{137}Cs$ concentrations in the muscle of deer in the autumn may therefore also be partly the result of the deer feeding on mushrooms. As a consequence,

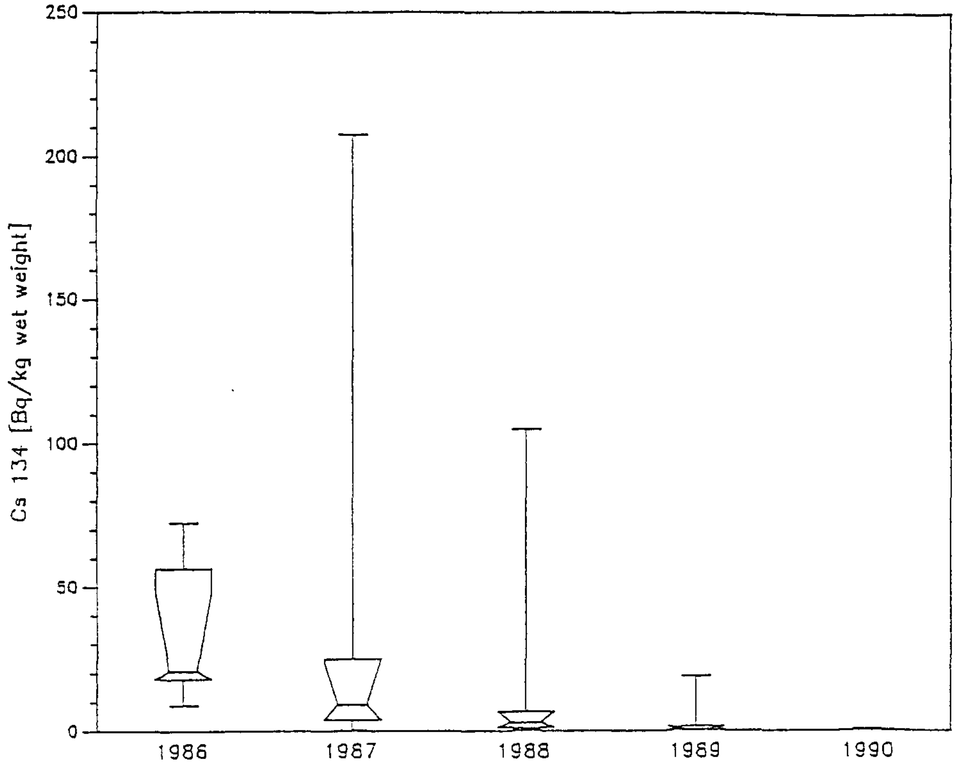


Figure 2. Temporal development of the $^{134}Cs$ contamination of muscle tissue in roe deer from 1986 - 1990.

$^{137}Cs$ concentrations in our samples from 1988 were also found to reach nearly 500 Bq/kg muscle tissue. These maximal values were not again reached in 1989 or 1990 (Fig.1).The concentrations of $^{134}Cs$, which has a much shorter half-life than $^{137}Cs$, reached 0.6 Bq in 1989 and 0.3 Bq in 1990 (median values). The physical half-life of $^{137}Cs$ is about 30 years, that of $^{134}Cs$ only about 2 years (Schötzig and Schrader 1986). From the original radiocesium that fallout after the reactor accident in 1986, most of the $^{134}Cs$ must have therefore already decayed. This may explain the very small amounts of $^{134}Cs$ found in the muscle of deer in 1989 and 1990, compared to the values from 1986 and 1987 (Fig.2). On the other hand, the environmental concentration of $^{137}Cs$, according to its half-life, must have remained virtually unchanged. Nonetheless, the $^{137}Cs$ concentrations in deer from 1989 and 1990 were much lower than in 1986 and 1987 (Fig.1). This corresponds well to the situation in the total (human) diet. Data obtained from duplicate samples of daily meals from several hospitals in Hesse show that in spring of 1989 the concentration of $^{137}Cs$ in the total diet was only 0.32 Bq/kg compared to 2.92 Bq/kg in the spring of 1987 (arithmetic mean, Georgii et al. 1990). Apparently, in the meantime the radiocesium from the reactor accident had become immobilized in the soil and therefore entered the

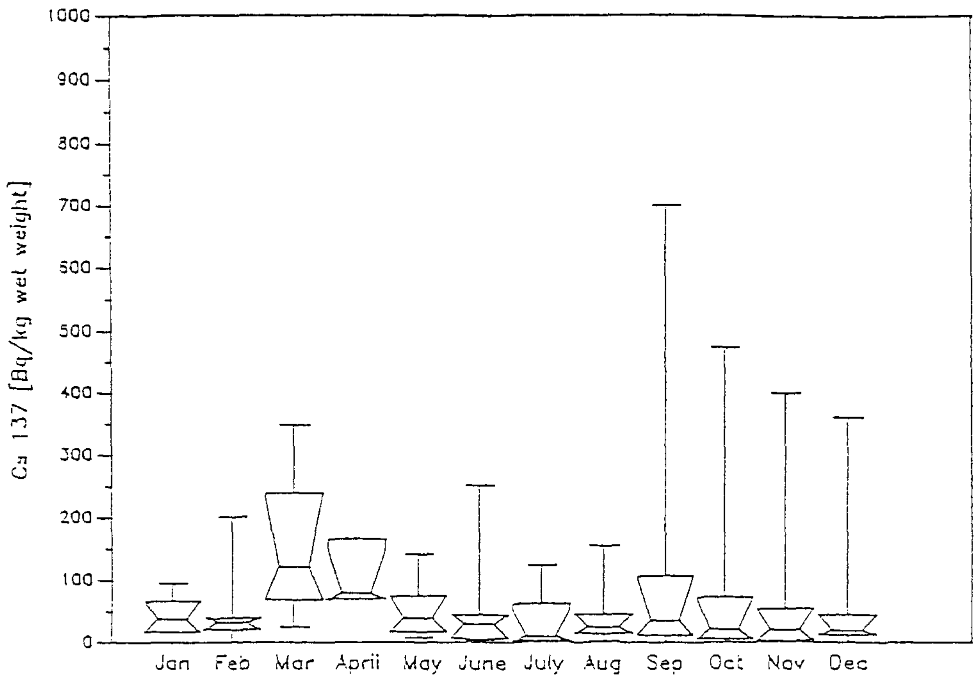


Figure 3. $^{137}Cs$ concentration in muscle tissue from roe deer in 1987.

food chain to only a very limited extent. In clay-containing sediment, radiocesium is found in the lattice position between silicate-layer regions normally occupied by potassium (Kaminski 1991). This is apparently also the case in soil (Beckmann and Faas 1992, Bunzl et al. 1992, Selnaes and Strand, 1992).

Compared to the concentrations of the naturally occurring nuclide $^{40}K$ (physical half-life of approximately 1.276 billion years, Schötzig and Schrader 1986) in deer muscle, the amounts of $^{137}Cs$ found in 1990 were exceedingly small (Fig.1). The average, temporally constant, content of $^{40}K$ in muscle of the deer examined in the present study was found to be 110 Bq/kg and was therefore 52 times greater than the $^{137}Cs$ values from 1990 (For the sake of comparison: total diet in 1981; $^{137}Cs$ 0.32 Bq/kg, $^{40}K$ 91 Bq/kg, Georgii et al. 1990).

By measuring the contamination of muscle tissue from deer it was possible to estimate the extent and temporal development of the $^{134}Cs$ and $^{137}Cs$ burden to the food chain. The data in Hesse from roe-deer, serving as biological indicator, show that the radiocesium released by the reactor accident in Chernobyl and transported to Germany and throughout Europe is now entering the food chains in only marginal amounts. The values for deer have returned to the levels measured before the reactor accident (Kreuzer and Hecht 1988a). They are many times lower than the corresponding levels of the naturally occurring nuclide $^{40}K$.

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Received January 20, 1993; accepted April 30, 1993.