MECHANISMS OF CESIUM TRANSFER IN FOREST ECOSYSTEMS OBTAINED FROM CONTINUOUS MONITORING OF ROEDEER CONTAMINATION

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ABSTRACT

At a roedeer population from a prealpine forest area (1600 km²) periodic contamination maxima in autumn, a slow overall decrease with an effective ecological half-time of 2,6 +/- 0,4 years and a regional pattern with characteristic small-scale variations representing the transfer of Cs radionuclides from the soil to the animals are observed. The depth distribution of Cs radionuclides in the layered forest soil is peaked in the uppermost humic layer and it is inferred that binding to organic substances plays an important role in the fixation of these radionuclides. This is corroborated by observations in a highmoor, where the shape of the depth distribution and the transfer to plants turned out to be rather similar to those of forest soils and at fertilized forest areas, where the transfer factor was significantly reduced.

INTRODUCTION

In the glacially formed prealpine region of Oberschwaben in the south west of Germany the contamination with Chernobyl fallout is among the highest in central Europe. The specific activity of Cs radionuclides in roedeer from this area, grazing mainly in forests, is higher than for other animal species and decayes only slowly in time /1/. Additionally it exhibits a characteristic seasonal structure /1,2/, which was similarly observed for roedeer from Sweden /3/ and from Bavaria /4/, and a small-scale regional structure, which was well reproduced over several years. We propose that these structures are related to the particular type of speciation of Cs radionuclides in layered forest soils, in particular to their association with organic substances in the uppermost humic layer /5-9/.

RESULTS AND DISCUSSION

In collaboration with local forest authorities the specific activities of Cs-137 and Cs-134 in most of the roedeer shot in this area - about 800 samples per year - have been measured gammaspectrometrically since 1987. The time dependence of the roedeer contamination - in fig. 1 the arithmetic mean over two weeks is shown - exhibits periodic contamination maxima in autumn, which are correlated with the well-defined season of mushrooms. Several mushroom species - among them the abundant edible species chestnut boletus (xerocomus badius) - have extraordinarily high cesium transfer factors /1/ and mushrooms are part of the diet of roedeer in autumn /3/. Therefore grazing of mushrooms is considered to be mainly responsible for the steep increase of roedeer contamination in autumn and its subsequent decrease is due to the abrupt end of the mushroom season. An additional reason for the in-

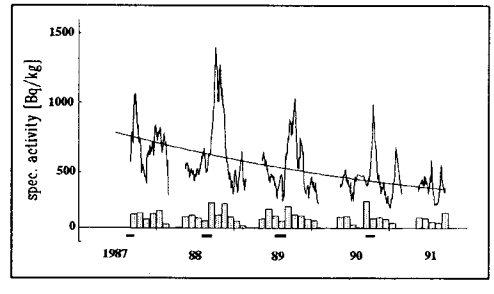

fig. 1: Specific activity of Cs-137 in roedeer meat versus time. Amount and season of mushrooms is indicated on the time scale.

creased contamination levels may be the general increase of roedeer intake in autumn /4/. The overall effective ecological half-time of the specific Cs-137 activity in the roedeer population, obtained from an exponential least-squares fit to all existing data for 4 years of monitoring, is 2,6 +/- 0,4 years.

Within this rather small and geologically uniform region (glacially formed muraines) the radiocesium (Cs-134 and Cs-137) contamination levels of individual animals varied widely between less than 10 and more than 3000 Bq/kg. The regional distribution of the contamination (individual animals were attributed to the sites of shooting), on the other hand, appeared to be stable over several years exhibiting small areas with groups of animals showing substantial contamination (fig. 2). Taking into account the restricted grazing areas of individual animals it is proposed that this contamination pattern reflects the pattern of local transfer factors from soil to roedeer via grazing plants. This was studied in detail in the largest forest of this area with a spatial resolution of 0,5 x 0,5 km², where differences of about a factor 50 in local transfer factors soil-roedeer were obtained between the northern and southern part of this forest (fig. 3).

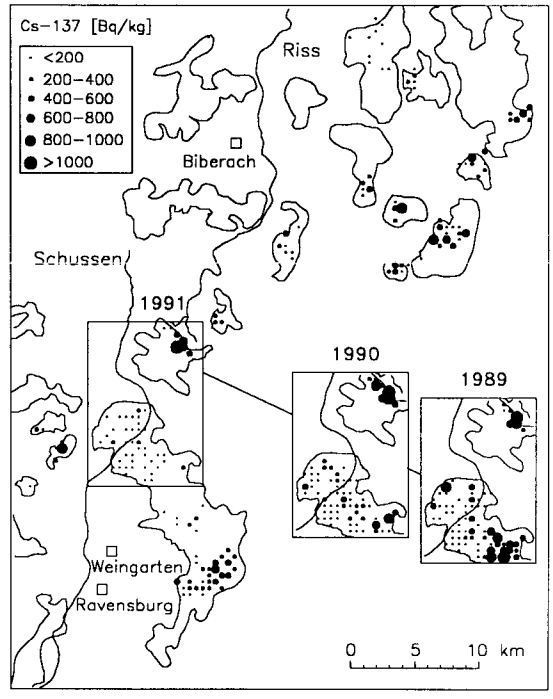

fig. 2: Regional distribution of specific Cs-137 activity of roedeer in southern Germany 1991. Inset shows the years 90 and 89. Each dot represents the average value of samples from an area of 0,5x0,5 km² .

These observations can be explained by (i) local variations of the availability of Cs radionuclides in the forest soils for the uptake by grazing plants or (ii) local changes of the abundances of grazing plants with different plant-specific transfer efficiencies. Since a similar pattern was obtained for the transfer factors soil-blackberry (fig. 4), we conclude that the type of binding of Cs radionuclides in the forest soils, i. e. the bioavailability in soil, is of major importance for the

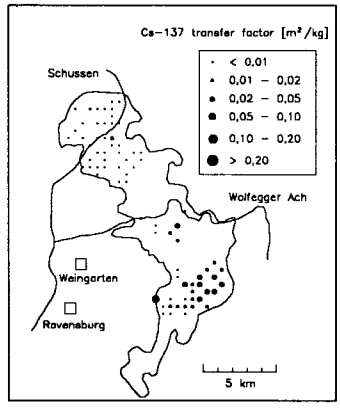

fig. 3: Cs-137 transfer factor soil-roedeer for the forest area Altdorfer Wald. Samples taken 1991. Dot representation as in fig. 2.

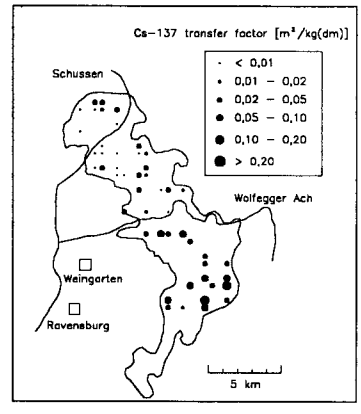

fig. 4: Cs-137 transfer factor soil-blackberry measured 1991.

contamination pattern.

The investigation of the depth distribution of Cs radionuclides in the soil of this forest revealed a high fraction of Cs radionuclides from the Chernobyl fallout still present in the uppermost humic layer of the soil, i.e. not deeper than 4 cm, in accordance with results for several other European forests /6-9/. A depth profile obtained from a sampling side in Altdorfer Wald is shown in fig. 5 together with the layering of the soil. Since the uppermost soil layer mainly consists of organic substances we presume a rather strong binding of Cs to organic substances, which prevents Cs radionuclides from transport to larger depths. This is in accordance with the results of laboratory experiments showing a high retention of Cs in O horizons /5/. The transfer factors soil-plant in this forest vary with the thickness of both O and A_h horizons showing highest values for total thicknesses as low as 2 cm (fig. 6), which emphasizes the importance of a well-developped O horizon for Cs immobilization. Another corroboration comes from depth profiles and transfer factors to plants measured in sphagnum bogs of this region. Despite of the lack of mineral components and layering of these soils, the shape of the depth profile in these soils is quite similar to that in forest soils (apart from an extension towards greater depths, fig. 7) and transfer factors soil - plants do not differ as much for plant species growing both in forest and sphagnum bogs /2/.

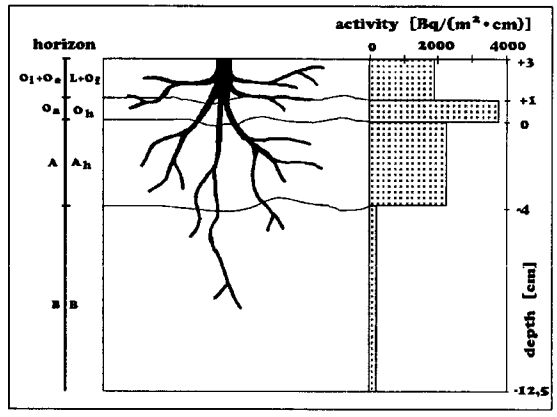

fig. 5: Layering of soil horizons and Cs-137 depth profile in a forest soil from Altdorfer Wald (20.12.90).

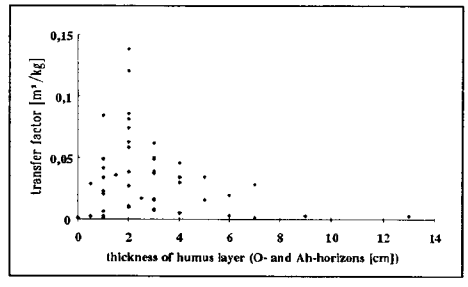

fig. 6: Cs-137 transfer factor soil-blackberry versus thickness of humus layer (O- and A_h-horizons).

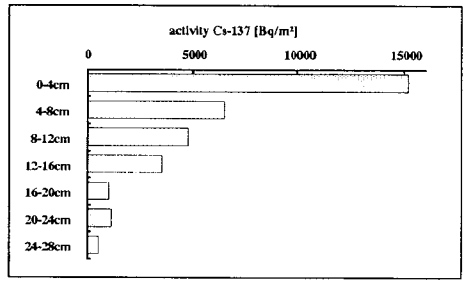

fig. 7: Depth profile of Cs-137 in sphagnum bog of Brunnenholzried.

As a consequence organically bound Cs radionuclides will be remobilized by the decomposition of their organic carriers as proposed by Dörr and Münnich /10/ and thus become available for the uptake by plants. Thus this system is very sensititve to changes of the chemical milieu, which can e.g. be induced by fertilizer treatment of the forest soil. Correspondingly, on a forest area treated with a fertilizer consisting mainly of $CaCO_3$ prior to the Chernobyl contamination, the transfer factor for several plants is significantly reduced as compared to a neighbouring untreated forest area (fig. 8). This effect might be explained by (i) the known faster decomposition of organic matter after liming inducing higher concentrations of ions in the soil solution; (ii) the definition of the transfer factor itself: the above-ground biomass of the bottom layer plants regarded on the limed field exceeds the biomass on the controll area considerably; or (iii) an enhancement of Cs association with organic matter.

CONCLUSION

The observed seasonal and regional structures in the radiocesium contamination of the roedeer population of a prealpine forest (picea abies) area emphasize the importance of the organic speciation of Cs radionuclides from the Chernobyl fallout in forest soils with respect to transfer processes.

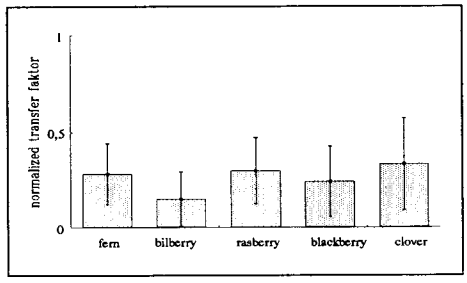

fig. 8: Relative reduction of Cs-137 transfer due to fertilizer for different plants from forest soil treated with a fertilizer containing 83% $CaCO_3$. The normalization is with respect to untreated soil.

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