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Activity levels of Cs 137 and K 40 in the skin and the associated structures of a cow following the Chernobyl accident

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ABSTRACT

The activity distributions of Cs 137 and potassium (K 40) have been investigated in all structures which are usually assigned to the skin of a cattle. The cow had ingested heavily contaminated forage following the Chernobyl fallout. It was found that the average activity concentrations of Cs 137 and K 40 in the skin are 33.6 Bq/kg and 18.8 Bq/kg, respectively. The activity concentration of Cs 137 in muscle tissue of the femur is ten times greater than the corresponding value in the skin, whereas the activity concentrations of K 40 differ by a factor six.

1 Introduction

In comparison to a single intake it is of particular interest to study the distribution of radionuclides in the body of domestic animals after a long-term uptake of radionuclides. ICRP assumes that cesium and potassium are deposited in a similar way and that both radionuclides are distributed homogenous in the whole body. Continuous ingestion of potassium leads to a equilibrium activity in the body. Less is known about the activity distribution of Cs 137 after a long-term ingestion. Therefore measurements of the activity concentrations of Cs 137 and the naturally occuring K 40 were carried out in samples of the skin and the associated structures (claws and horns) of the cow.
The cow was born in a high contaminated region of Styria, Austria , two years after the fallout following the Chernobyl accident. Therefore the activity level of Cs 137 is caused by the activity administered by the mother-cow during pregnancy and the activity due to chronically ingestion of high contaminated forage during about four years.

2 Experimental Procedures

The cow was slaughtered in November 1992 and dissected in anatomical parts. All samples were deep frozen immediately after slaughtering and had to be thawed

before measuring. Exclusively mechanical procedures were performed during separation of complex structures of the samples in their physiological components /1/. The activities of Cs 137 and K 40 in the samples were determined simultaneously by gamma counting with the help of semiconductor detectors and the standard software. Marinelli-beakers and small cylindrical containers made of perspex were used as containers for the samples.

3 Experimental Results

All activities are related to November 14, 1992 (day of slaughtering) and corrected with respect to the self attenuation of the photons within the sample material and also due to moisture losses during freezing, thawing and preparation. Self attenuation factors were computed by means of the Monte Carlo program EGS4. Results for the activities and their ratios are presented with a confidence level of 2σ.

3.1 Skin

The activity concentrations of Cs 137 and K 40 in the samples of the skin range from (24.4 $\pm$ 1.8) Bq/kg to (59.6 $\pm$ 6.8) Bq/kg and from (14.2 $\pm$ 2.2) Bq/kg to (27.6 $\pm$ 12.7) Bq/kg, respectively.

Fig. 1 shows a box-and-whisker plot of the activity concentrations of Cs 137 and K 40 in 36 measured samples of the skin. The central box illustrates the median and the interquartile range, the whiskers tend out to the minimum and maximum observed values. Unusual values (outliers) removed from the bulk of the data are plotted as separate points. In general the values of the activity concentrations of Cs 137 show a broader distribution than the corresponding values of K 40. The far outside points in Fig. 1 refer to the activity concentrations of the skin near the origin of the horns. Besides this position also the skin nearby the claws showed a high external contamination.

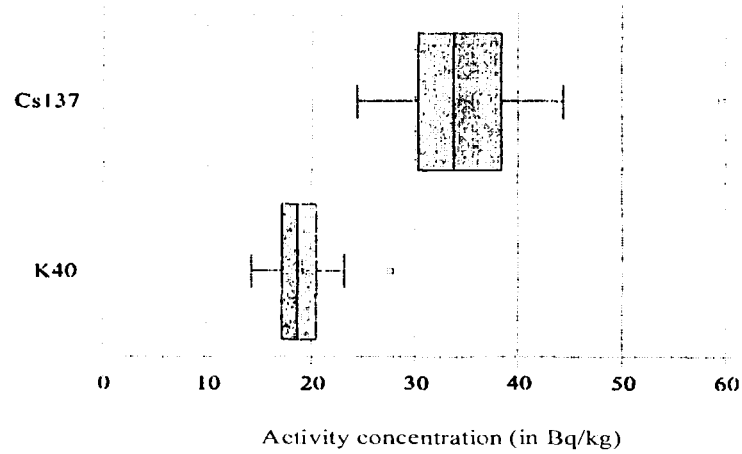

Figure 1: Box-and-whisker plot of the activity concentrations of Cs 137 and K 40 in all samples of the skin.

The activity concentrations of Cs 137 and K 40 of the whole skin (hair, epidermis, hypodermis) were determined with respect to the front part (head, pectoral limbs, neck), the mid part (back, abdomen) and the back part (pelvic limbs, tail) of the cow. Table 1 summarizes the average activity concentrations of Cs 137 and K 40, their ratios and the mean activities per unit area of the radionuclides with reference to the three parts of the cow.

Table 1. Activity concentrations of Cs 137 and K 40, activities per unit area and activity ratios of the skin with reference to the three parts of the cow (overall uncertainty: $\pm$ 2 σ).

Part	Activity concentration (Bq/kg)		Activity per unit area (mBq/cm^2)		Activity ratio
	Cs 137	K 40	Cs 137	K 40	
Front	36.9 $\pm$ 0.7	19.8 $\pm$ 0.7	31.7 $\pm$ 2.7	17.0 $\pm$ 1.5	1.87 $\pm$ 0.07
Mid	33.4 $\pm$ 0.6	19.0 $\pm$ 0.7	27.0 $\pm$ 2.2	15.4 $\pm$ 1.3	1.76 $\pm$ 0.04
Back	29.3 $\pm$ 0.7	17.0 $\pm$ 0.7	25.2 $\pm$ 2.6	14.6 $\pm$ 1.6	1.73 $\pm$ 0.07

Performing statistical U- and H-tests lead to the result that the mean values of the activity concentrations of Cs 137 and K 40 are significantly different at the 5 % level for the skin of the front and back part of the cow. There is also a significant difference of the Cs 137 activity concentrations of the front and mid part.
The highest values of the activities of Cs 137 and K 40 per unit area were found in a skin sample originating from regions near the mouth. This sample contained glandular structures (naso-labial glands).

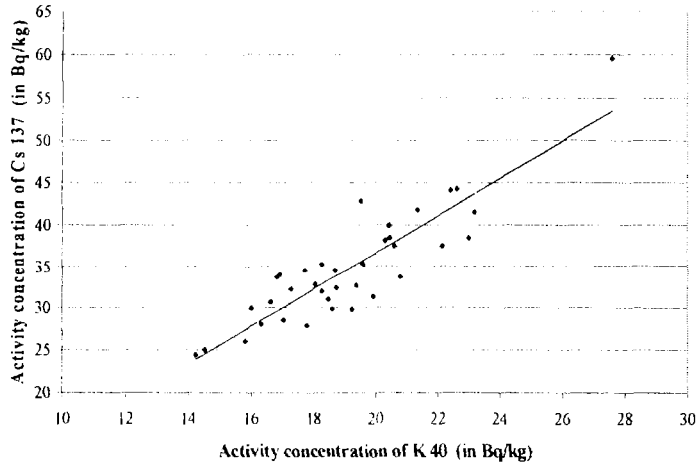

Figure 2: Scatter plot and linear regression line of the activity concentrations of Cs 137 and K 40 in all samples of the skin.

A scatterplot of the data set (36 samples) is shown in Fig. 2. The linear regression line also drawn in Fig. 2 indicates a strong correlation (coefficient of determination: 0.789) between the activities of Cs 137 and K 40. In Table 2 results of measurements and other quantities characterizing the skin are presented.

Table 2. Total activities, mean activities per unit area and other quantities of the skin (overall uncertainty: $\pm$ 2 σ).

Quantity	Cs 137	K 40
Total activity (Bq/kg)	1221.6 $\pm$ 65.1	681.6 $\pm$ 88.6
Average activity per unit area (mBq/cm^2)	28.2 $\pm$ 4.7	15.7 $\pm$ 3.1

Total mass:	(36.31 $\pm$ 0.36) x 10^3 g
Thickness (range):	3.5 - 10.5 mm
Total surface:	(4.33 $\pm$ 0.26) m^2
Mean activity ratio:	1.79 $\pm$ 0.26

(Exception: Overall uncertainty of total mass is given as $\pm$ 1 σ).

In Table 3 the activity concentrations of Cs 137 and K 40 of the skin are compared with the corresponding values of different components of the femur. The scheduled subjects start at the center of the os femoris and proceed throughout the muscle tissues to the covering skin.

Table 3. Activity concentrations of Cs 137 and K 40 in different components of the femur (overall uncertainty: $\pm$ 2 σ).

Sample	Mass (g)	Activity concentration (Bq/kg)		Activity ratio
		Cs 137	K 40	
Bone marrow	425.2	2.6 $\pm$ 0.3	1.5 $\pm$ 0.7	1.74 $\pm$ 0.87
Fat, connective tissue	97.4	31.0 $\pm$ 3.9	8.4 $\pm$ 5.4	3.71 $\pm$ 2.40
Trabecular bone	1 821.9	8.2 $\pm$ 0.4	5.3 $\pm$ 0.7	1.55 $\pm$ 0.24
Cortical bone	1 325.5	16.8 $\pm$ 0.8	10.6 $\pm$ 1.0	1.57 $\pm$ 0.19
M. gracilis	15 109.2	374.2 $\pm$ 6.6	119.4 $\pm$ 3.0	3.13 $\pm$ 0.10
Biceps femoris	11 462.7	335.0 $\pm$ 7.2	111.8 $\pm$ 3.2	2.99 $\pm$ 0.11
Skin	5 901.2	31.5 $\pm$ 3.9	17.9 $\pm$ 7.0	1.71 $\pm$ 0.72

Because of the high content of fat in the trabecular bone, the activity concentrations of the trabecular and the cortical bone differ by a factor two. In comparison to muscle tissues (M. gracilis, biceps femoris) /2/ the activities of Cs 137 and K 40 in the skin are lower by a factor ten and six, respectively.

3.2 Claws

Fig. 3 shows a simplified sagittal section of the claw. All subjects labelled in Fig. 3 were carefully prepared before measuring. The experimental results are presented in Table 4.

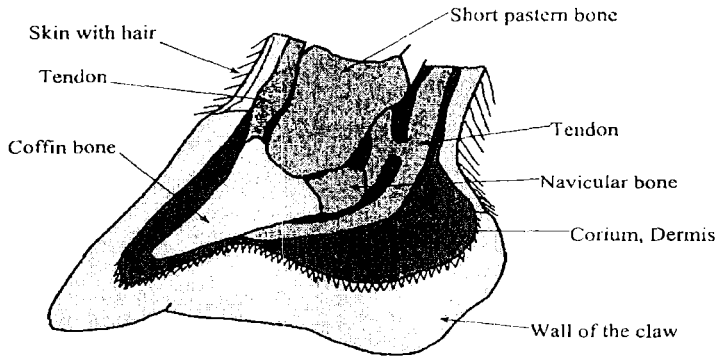

Figure 3: Sagittal section of the claw.

Table 4. Sample masses, activity concentrations of Cs 137 and K 40 and their ratios of different components of the claws (overall uncertainty: $\pm$ 2 σ).

Sample	Mass (g)	Activity concentration (Bq/kg)		Activity ratio
		Cs 137	K 40	
Coffin bones	312.2	20.9 $\pm$ 2.0	13.4 $\pm$ 2.4	1.56 $\pm$ 0.32
Short pastern bones, navicular bones	333.8	14.1 $\pm$ 1.3	10.1 $\pm$ 1.8	1.40 $\pm$ 0.28
Tendons: deep digital flexor and common digital extensor	71.2	33.4 $\pm$ 2.9	24.0 $\pm$ 7.5	1.39 $\pm$ 0.45
Corium (dermis)	142.4	54.3 $\pm$ 6.8	27.1 $\pm$ 6.6	2.00 $\pm$ 0.61
Layer between corium and epidermis	114.3	58.1 $\pm$ 7.3	33.0 $\pm$ 7.7	1.71 $\pm$ 0.44
Wall of the claws (epidermis)	776.4	36.7 $\pm$ 2.3	31.2 $\pm$ 3.0	1.18 $\pm$ 0.14
Skin	280.2	44.3 $\pm$ 4.2	22.6 $\pm$ 3.6	1.96 $\pm$ 0.36
Dewclaws	268.5	58.4 $\pm$ 4.9	31.9 $\pm$ 3.9	1.83 $\pm$ 0.27

3.3 Horns

Fig. 4 shows a simplified longitudinal section through the horn. The activity concentrations of the radionuclides under investigation of the bones of the femur (Table 3), the claws (Table 4) and the horns (Table 5) are comparable.

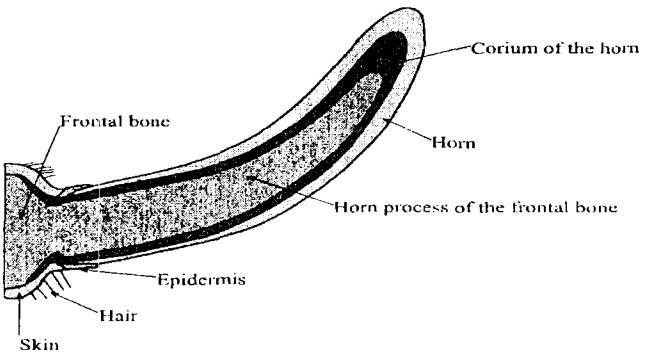

Figure 4: Longitudinal section through the horn.

Table 5. Sample masses, activity concentrations of Cs 137 and K 40 and their ratios of different structures of the horns (overall uncertainty: $\pm$ 2 σ).

Sample	Mass (g)	Activity concentration (Bq/kg)		Activity ratio
		Cs 137	K 40	
Horn	462.2	17.1 $\pm$ 1.2	3.6 $\pm$ 1.0	4.75 $\pm$ 1.36
Skin	91.2	59.6 $\pm$ 6.8	27.6 $\pm$ 12.7	2.16 $\pm$ 1.00
Hornprocess and corium	277.0	23.0 $\pm$ 2.2	11.3 $\pm$ 4.0	2.03 $\pm$ 0.74
Frontal bone	173.6	20.5 $\pm$ 2.6	12.7 $\pm$ 4.7	1.61 $\pm$ 0.58

4 Conclusions

It can be seen from this investigation that Cs 137 is not distributed homogenously in different tissues of the cow. All activity ratios are > 1. In general the activity concentrations of K 40 show a smaller distribution than the values of Cs 137. The activity concentrations of Cs 137 and K 40 in the epidermis of the claws and horns are different by a factor 2.1 and 8.7, respectively, although these samples consist of the same tissue.

Acknowledgment

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Literature

/1/ R.D. Frandson, T.L. Spurgeon: *Anatomy and Physiology of Farm Animals*; Lea & Febiger, 5th Edition, 1992.

/2/ H. Rabitsch, E. Pichl, J. Pletz, G. Kahr: *Investigations to the distribution of Cs-137 and K-40 in a cow*; Proceedings of the International Congress on Radiation Protection (IRPA 9), Vol. 3 (170 - 172) 1996.