Dosimetry of wild organisms and their natural dose

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Outline

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1. Motivation

- ✓ To protect ecosystems from radiation, precise assessment of the radiation dose to wild organisms is important and necessary. However, the precise radiation dosimetry method has not yet been established for the wild organisms.

- ✓ In addition, though the background radiation dose rate in a contaminated environment is of fundamental importance for evaluating the effects of radiation on wild organisms living there, very few studies have evaluated it.

- ✓ The natural background radiation dose of the wild organisms in Rokkasho Village is important in relation with public acceptance of the JNFL nuclear fuel reprocessing plant.

We have developed the precise radiation dosimetry method for terrestrial mammalians and aquatic organisms and calculated their background dose rates.

2. Target organisms

Terrestrial mammalians

Small-sized

Mouse
(*Apodemus argenteus*)

Shrew mole
(*Urotrichus talpoides*)

Middle-sized

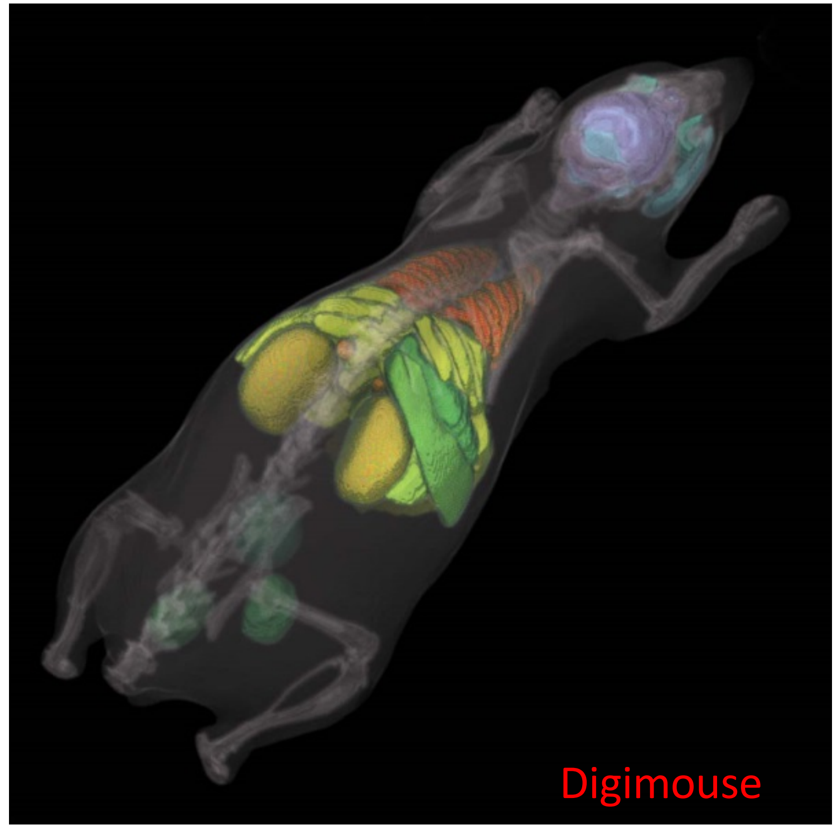
Red fox
(*Vulpes vulpes japonica*)

Raccoon dog
(*Nyctereutes procyonoides viverrinus*)

3. Voxel phantoms

Development of voxel phantoms
(Mouse / Shrew mole)

- Voxel phantoms of a male and female of mouse were based on the Digimouse [1, 2] developed by University of Southern California.
- Intestine parts were newly produced. Ovaries were incorporated instead of testes for a female phantom.
- The mouse phantom was also used for shrew mole with some adjustment of body size and weight.



1) B. Dogdas, D. Stout, A. Chatziioannou, and R. M. Leahy, 2007
2) D. Stout, P. Chow, R. Silverman, R. M. Leahy, X. Lewis, S. Gambhir, A. Chatziioannou, 2002.

Development of voxel phantoms
(Red fox)

- A red fox voxel phantom was constructed on the basis of tomographic images by magnetic resonance imaging technique (MRI) for a female fox caught in 2009.
- The phantom was also used for raccoon dog.

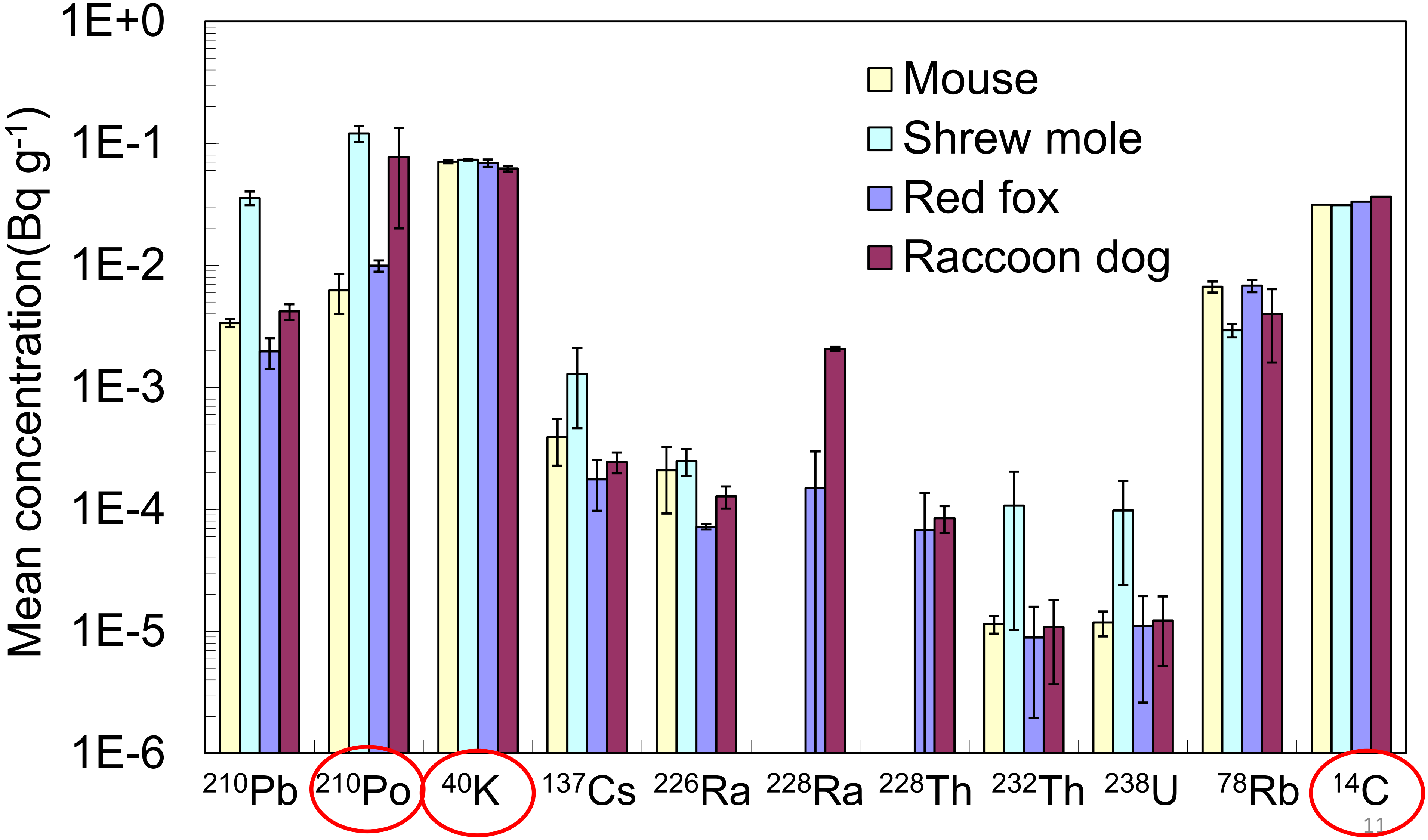
Dimensions and voxel sizes of our phantoms

Phantom	Body length (cm)	Weight (g-wet)	Voxel size(mm)			No. of voxels
			X	Y	Z	
Mouse (male/female)	7.1	13.4	0.087	0.087	0.080	2.2×10^{10}
Shrew mole (male/female)	8.1	16.7	0.091	0.091	0.091	2.2×10^{10}
Red fox (female)	76.6	3.58×10^{3}	0.78	0.78	2.0	2.8×10^{6}

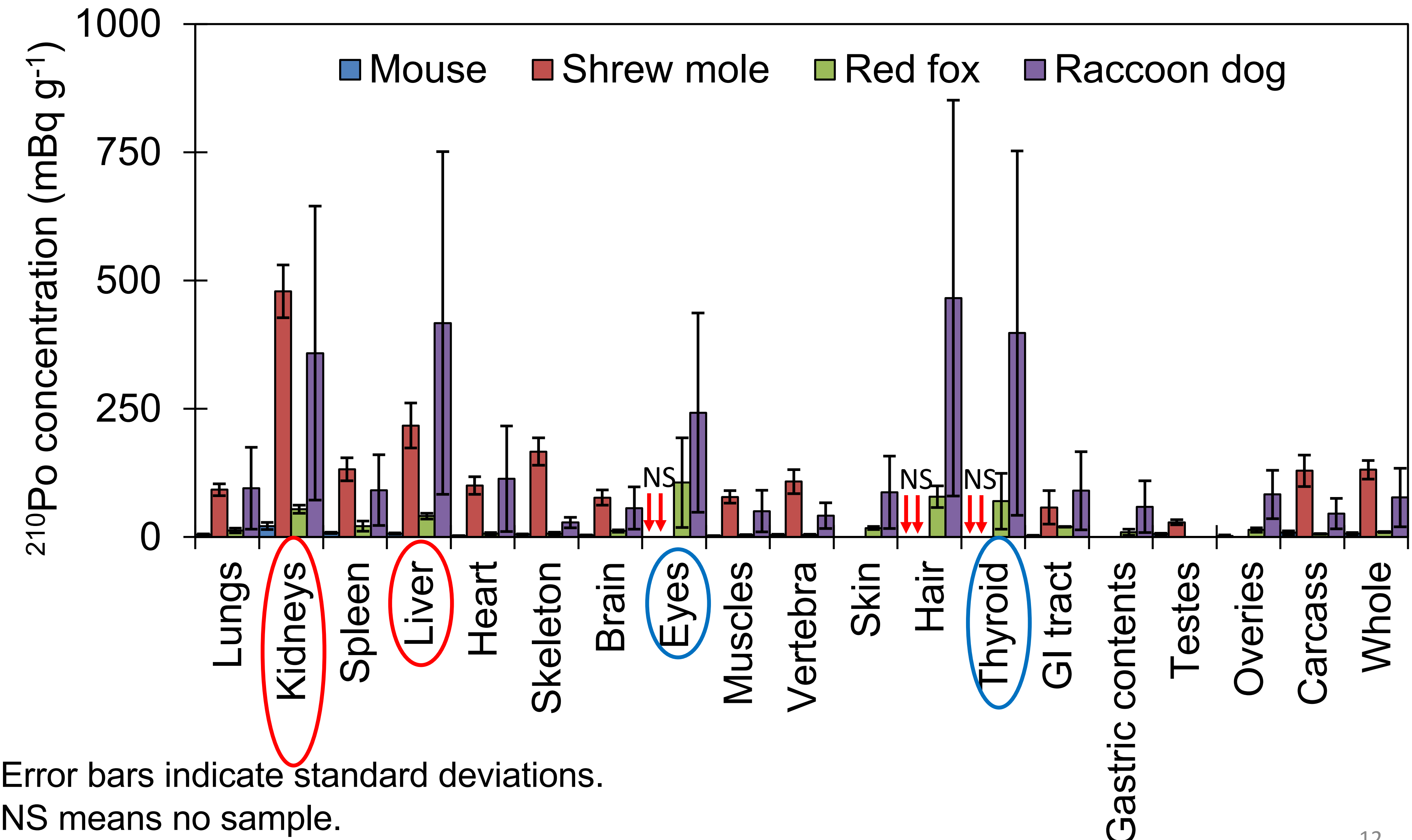
4. Dose rate calculation

- Internal radiation
  - Distribution of radionuclides in body (ex. ^{210}Po, ^{40}K)
  - Dose rate of each organ
  - Comparison (Our results / ERICA-tool)
- External radiation
  - On ground and in burrows
  - Cosmic rays
- Radon (Inhalation)
  - On ground and in burrows

Mean concentration of radionuclides in terrestrial mammalians



Mean ^{210}Po concentration in organs of mouse, shrew mole, red fox and raccoon dog.



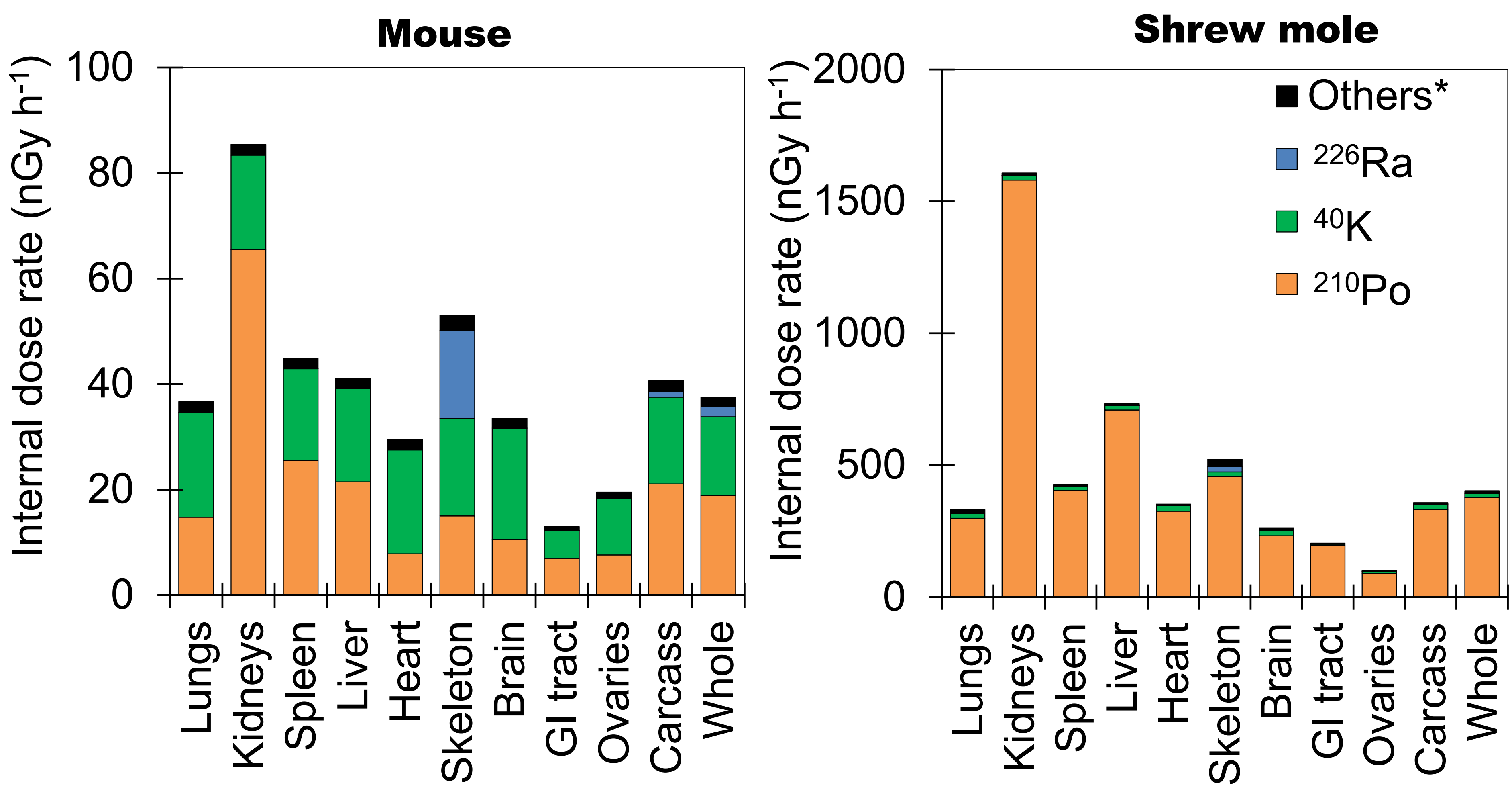
Error bars indicate standard deviations.
NS means no sample.
n=19 – 20 (mice), 16(shrew mole), 2 (female red fox and raccoon dog).

Internal radiation dose rate calculation

1. Their radiation dose rates were calculated by the Monte Carlo code (EGS4) using each voxel phantom and concentration of elements and radionuclides measured in organs.
2. Relative biological effectiveness (RBE) of alpha-particles is assumed to be “1”.
3. Our whole body doses were compared with those by ERICA-tool.

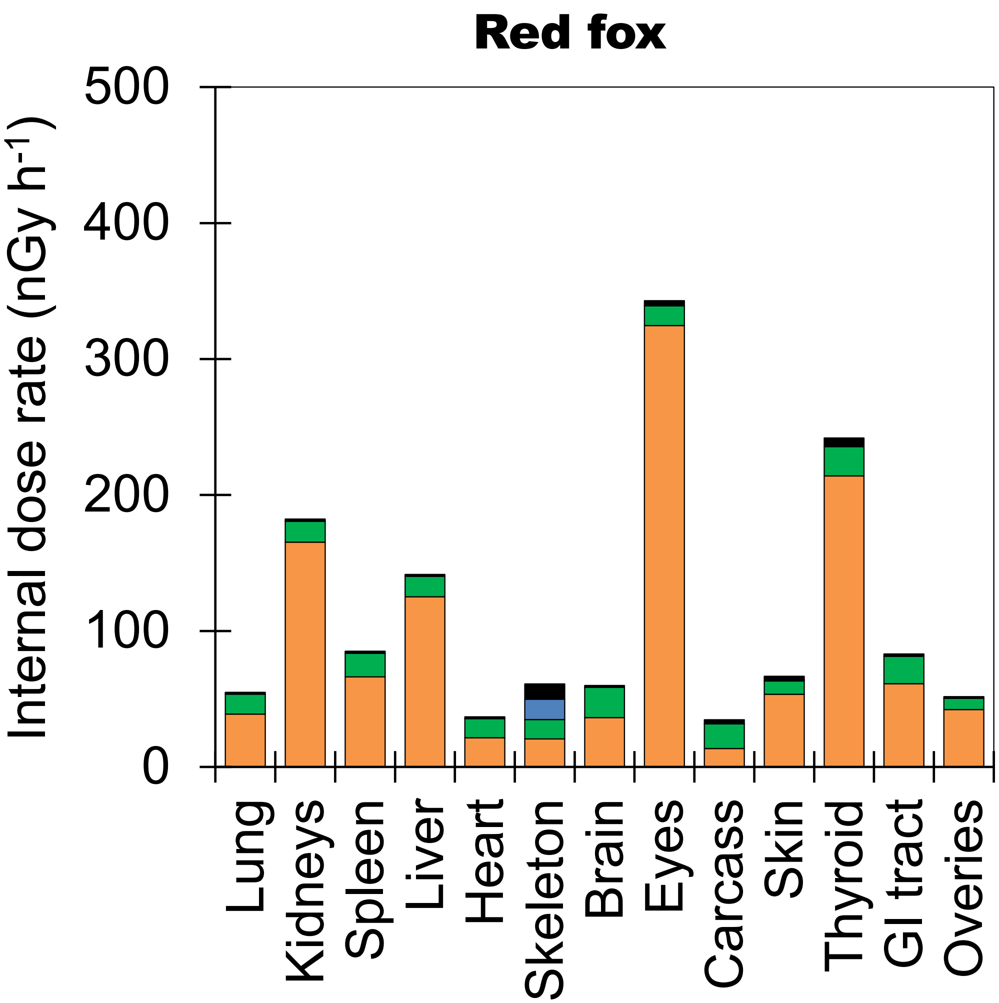
   Using ERICA-tool, an ellipsoid as body shape and homogeneous distribution of radionuclides in the body are assumed.

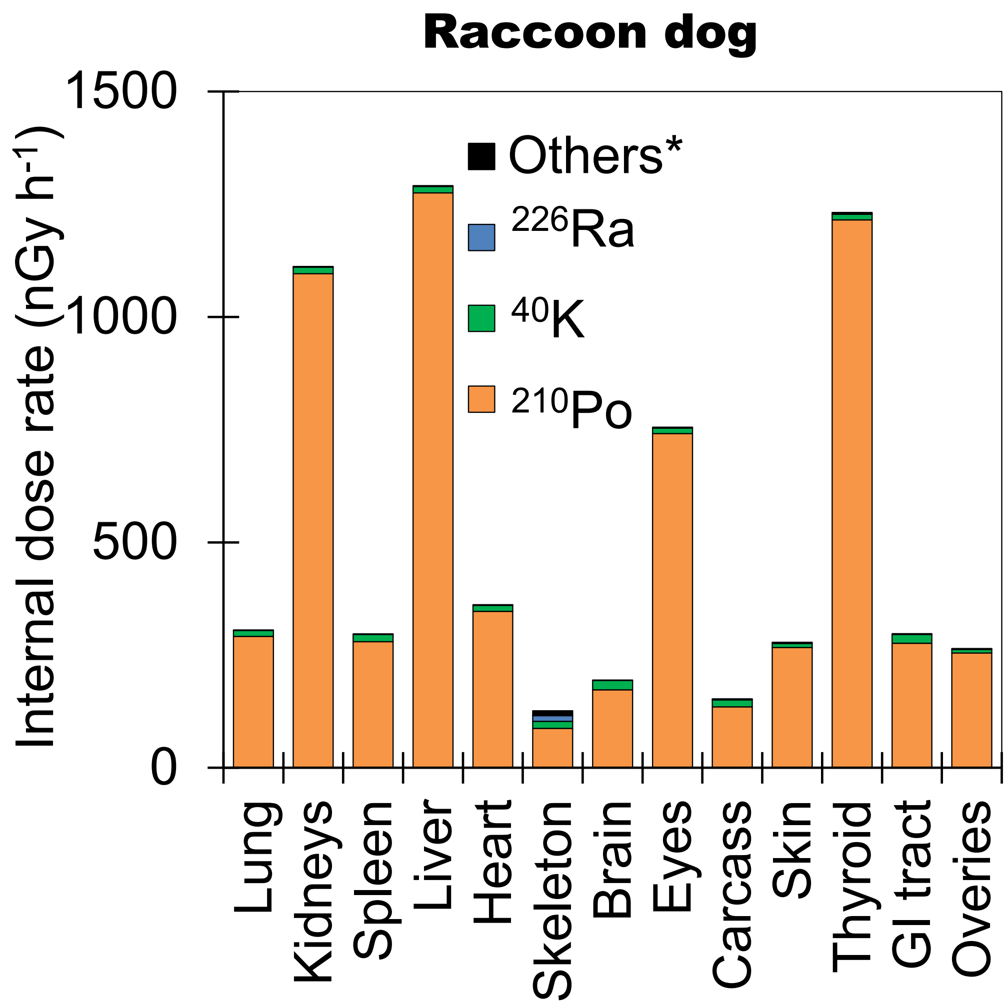
Internal dose rates of the female mouse and shrew mole



* Sum of ^{14}C, ^{87}Rb, ^{137}Cs, ^{210}Pb, ^{228}Ra, $^{228+232}Th$ and $^{234+238}U$

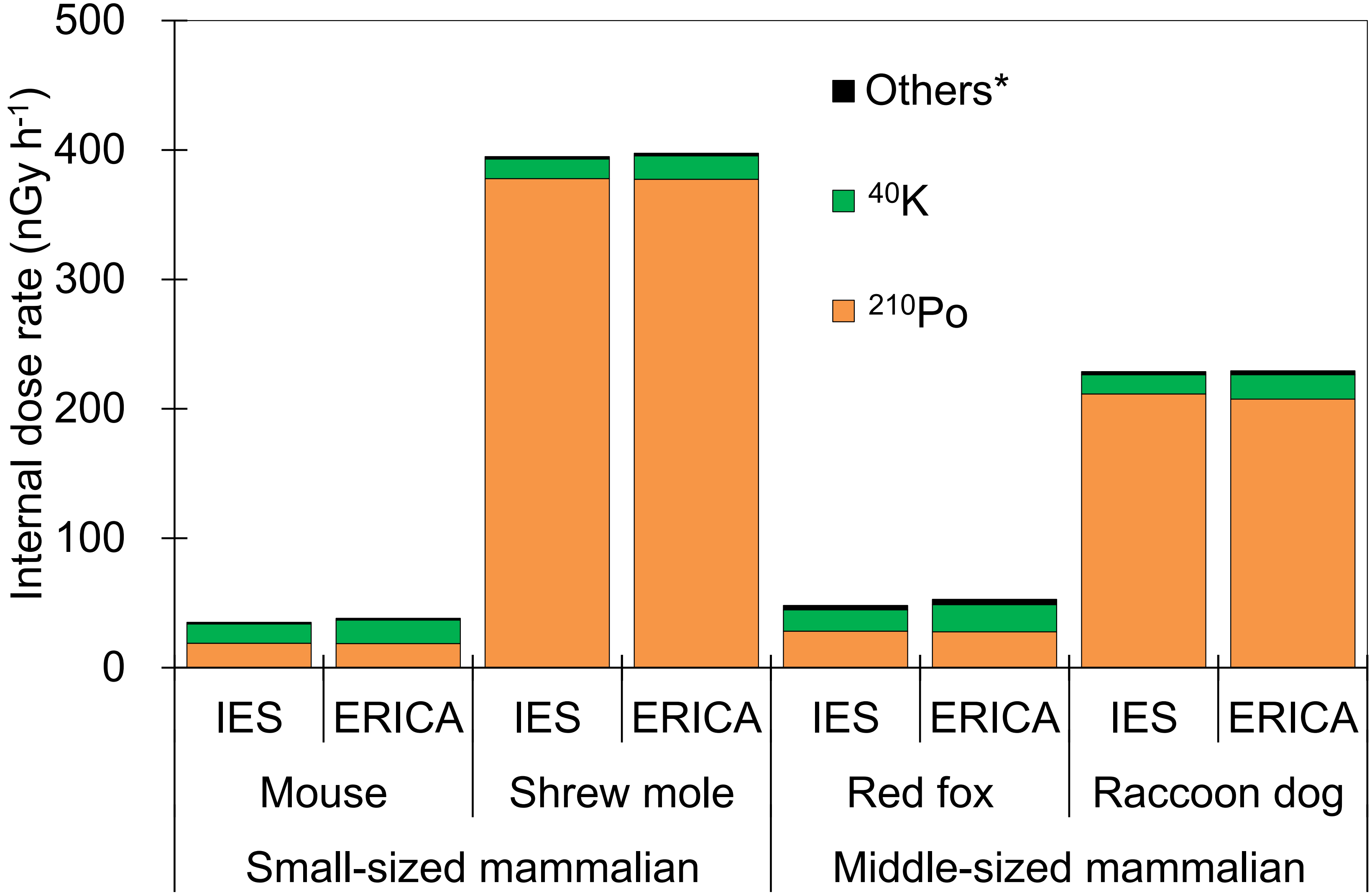
Internal dose rates of the female red fox and raccoon dog





* Sum of ^{14}C, ^{87}Rb, ^{137}Cs, ^{210}Pb, ^{228}Ra, $^{228+232}Th$ and $^{234+238}U$

Comparison of our whole body dose rates with those by ERICA-tool

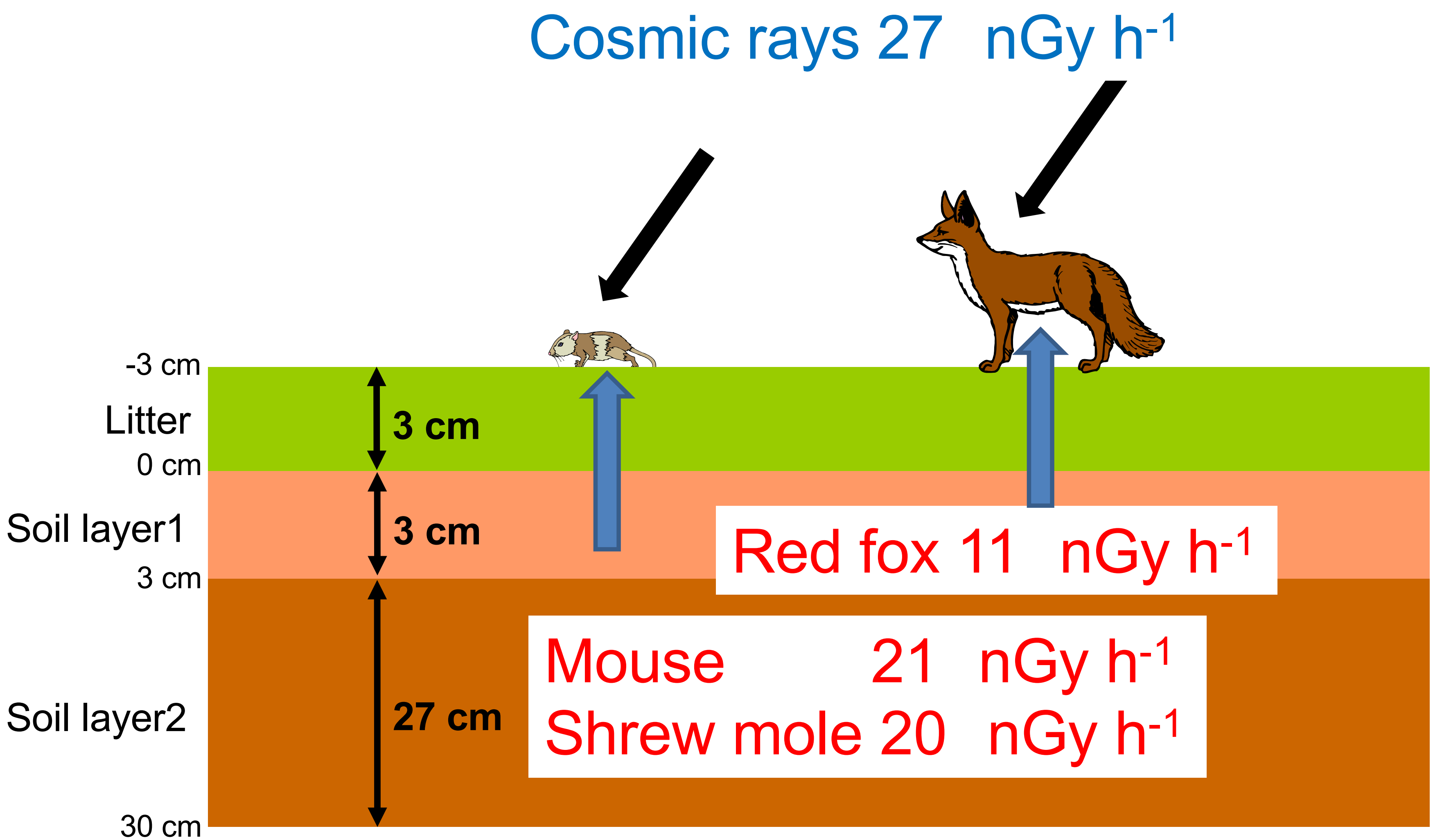


* Sum of ^{14}C, ^{87}Rb, ^{137}Cs, ^{210}Pb, $^{226,228}Ra$, $^{228,232}Th$ and $^{234+238}U$.
Values of ERICA are evaluated from whole body concentration of each radionuclide and DCCs by ERICA-tool.

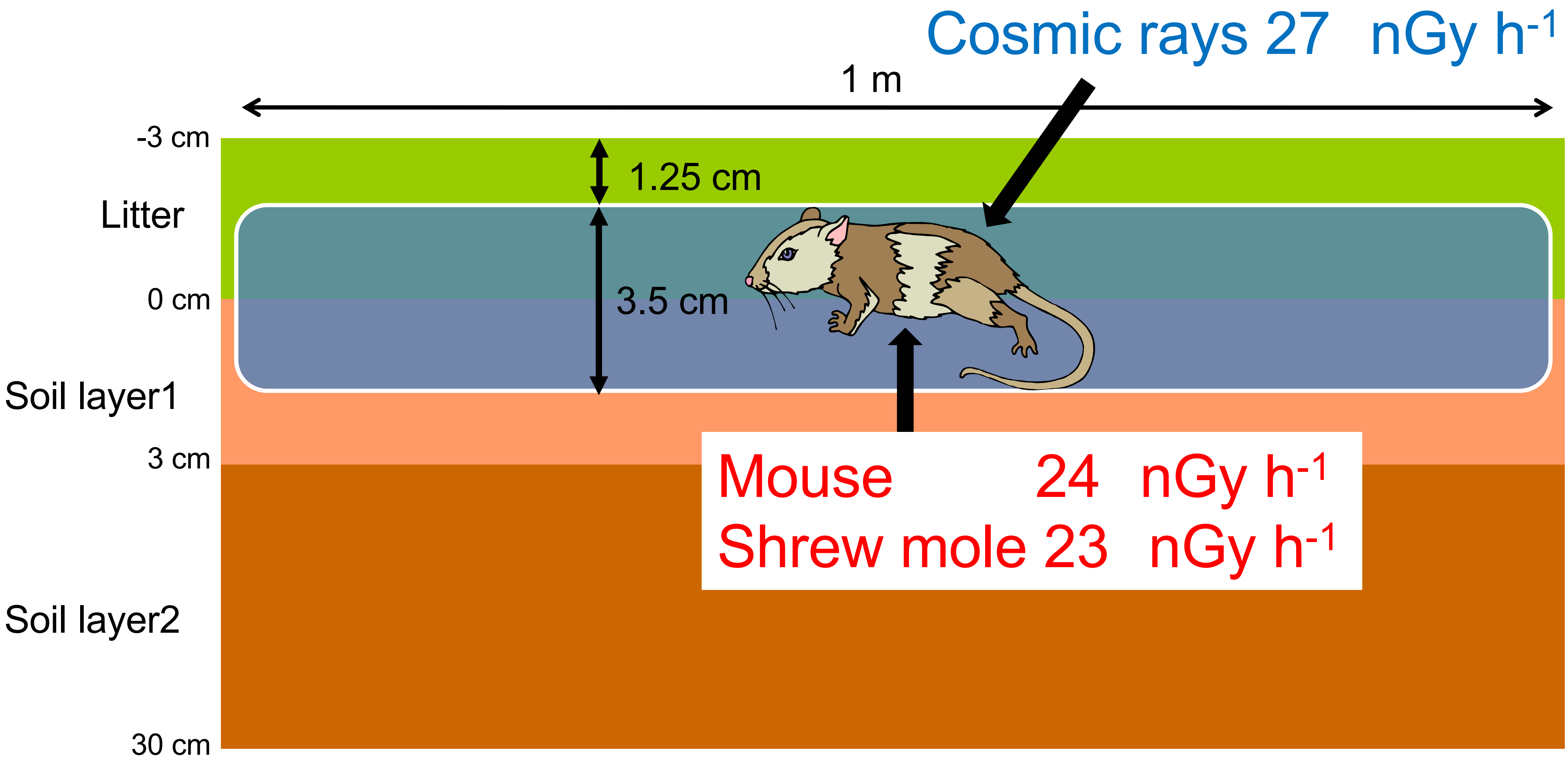
External radiation dose rate calculation

1. Soil horizons of a litter layer and two soil layers were assumed.
2. Dimensions of a burrow for the small-sized mammalian were cited from a literature (Higuchi et al., 1981).
3. Dimensions of a burrow for middle-sized mammalians were decided from mean sizes of six burrows found in Rokkasho.
4. External dose rate on ground and in the burrow were calculated by the Monte Carlo code based on UCPIXEL using these voxel phantoms.
5. Radiation from alpha-particles was not considered.
6. Concentrations of 14 elements and radionuclides including ^{137}Cs were analyzed in litters and soils collected in the forests and around burrows for middle-sized mammalians in Rokkasho.

Radiation on ground

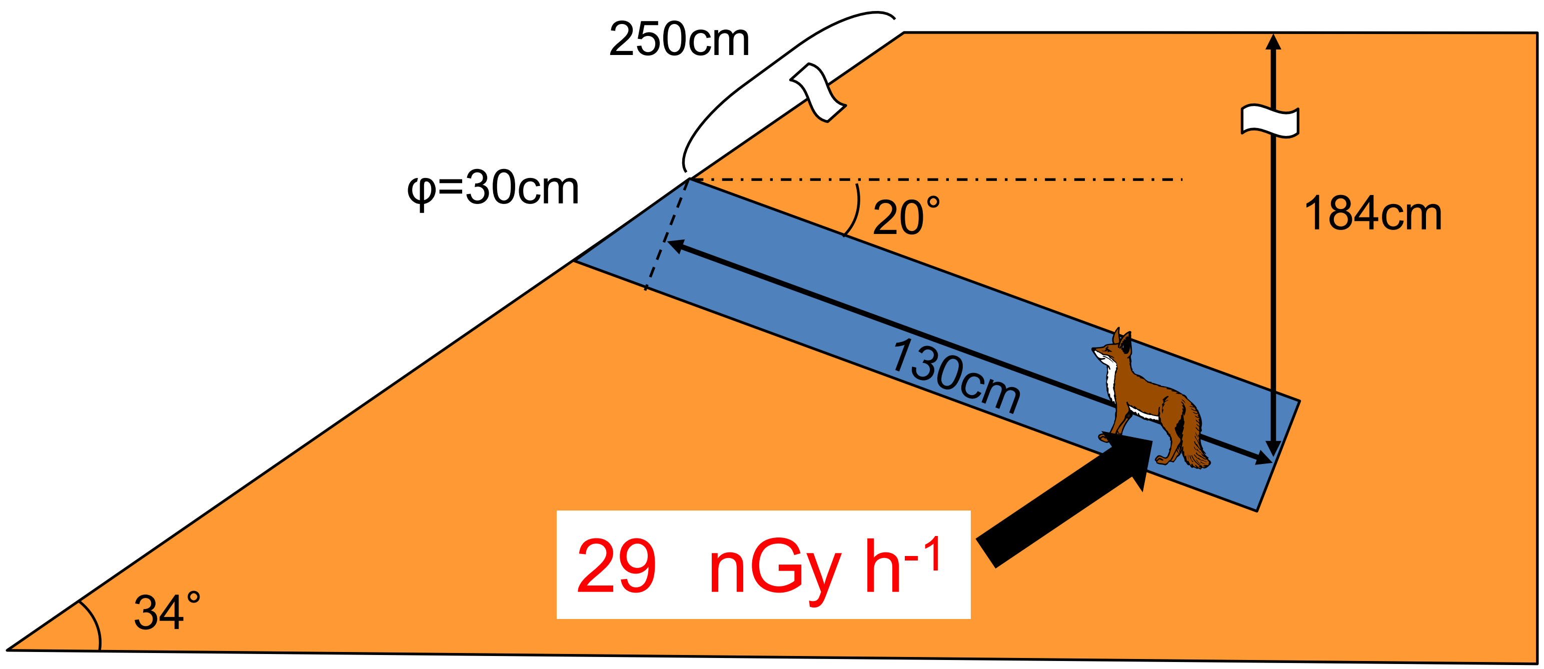


External radiation doses for the mouse and shrew mole in the burrow



Dimensions of a burrow for a small-sized mammalian were cited from a literature (Higuchi et al., 1981).

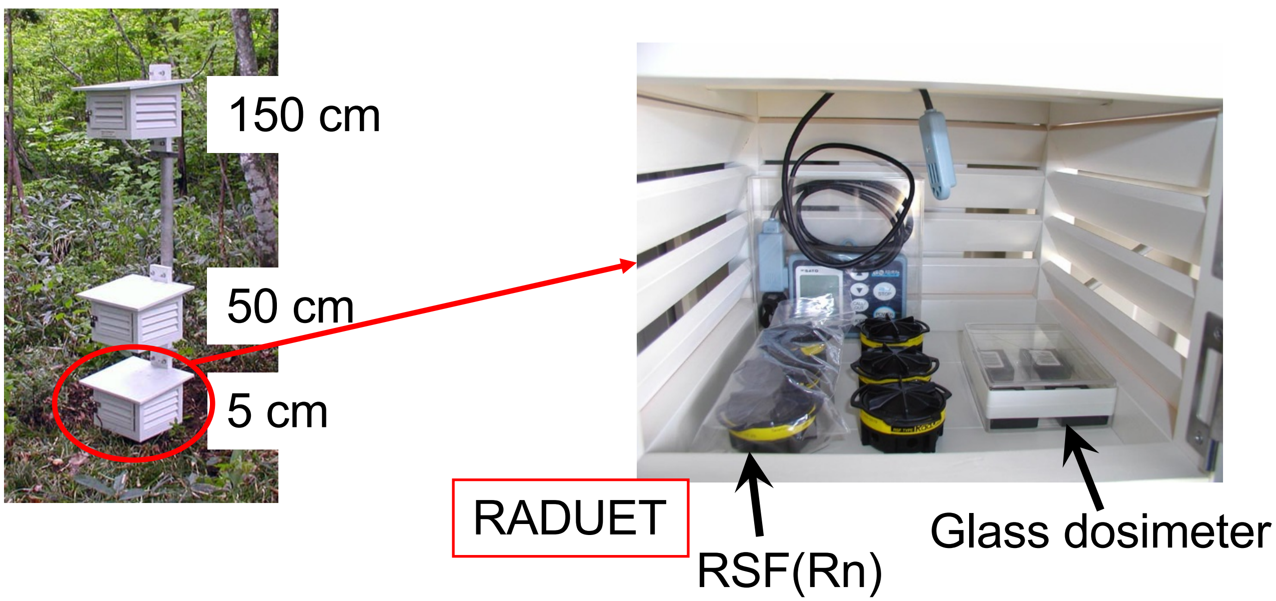
External radiation dose for the red fox in the burrow



Dimensions of a burrow for middle-sized mammalians were defined from the mean shape of six burrows found in Rokkasho.

Radiation from radon in air to these mammals

Mammalian	Location	Mean ^{222}Rn concentration ($Bq\ m^{-3}$)	Equilibrium factor	Dose conversion ($nGy\ h^{-1}$)($Bq\ m^{-3}$)$^{-1}$	
				Lungs	Bronchus
Mouse Shrew mole	On ground	6.5	0.27	2.85 [1)]	3.88 [1,2,3)]
	In a burrow	2.7×10^2	0.27		
Red fox Raccoon dog	On ground	5.5	0.27	0.92 [4)]	1.48 [4)]
	In a burrow	8.6×10^2	0.30		



References
1) Morken et al. (1966)
2) Strong and Baker (1996)
3) Hofmann et al. (2006)
4) Harley et al. (1992)

Natural radiation dose rates

Radiation source		Dose rate ($nGy\ h^{-1}$) Mouse	Shrew mole	Red fox	Raccoon dog
Internal		37	4.0×10^2	50	2.3×10^2
External [1)]		46 – 51	47 – 50	29 – 38	
^{222}Rn [2)]	Lungs	5.0 – 2.1×10^2		1.4 – 2.4×10^2	
	Bronchus	6.8 – 2.8×10^2		2.2 – 3.8×10^2	

1) Including dose rate from cosmic rays.
2) Evaluation from concentration of ^{222}Rn and its progenies on ground in forests and in burrows.

5. Summary

1. Voxel phantoms of 3 species terrestrial mammalians (a male and female of each mouse and shrew mole, a female red fox) were constructed for their internal and external dose rate calculation of each organs.
2. Their background dose rates were also calculated from concentrations of radionuclides in organs of each mammalian and environmental samples collected around their inhabit in Rokkasho.
3. Polonium-210 and ^{40}K in their body is an important radionuclide because of its high contribution to their internal radiation dose. The radiation dose to each organs significantly varied depending mainly on ^{210}Po.
4. Radiation dose rates from radon in air to terrestrial mammalians are especially high when they are in a burrow.
5. ERICA-tool gave a reasonable estimation for whole body internal dose by natural radionuclides.

Acknowledgement

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