Radionuclide activity concentrations in two species of reptiles from the Chernobyl exclusion zone

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INTRODUCTION

Various models/tools have now been developed to assess radiation exposure to wildlife (Beresford *et al*., in press[a]). Assessments of radiation exposure of reptiles may be required in some countries because many are protected species. However, there are few data for the transfer of radionuclides to terrestrial reptile species. For example, in the derivation of default transfer parameters for the ERICA-Tool (Beresford *et al*. in press[b]), with the exception of Cs and Sr, there were no published data available within the open literature.

In this paper, we present ^{137}Cs, ^{90}Sr and $^{238/239/240}$Pu activity concentrations, and concentration ratios (as used in a number of assessment models), for two species of terrestrial reptiles (*Lacerta agilis* (sand lizard) and *Natrix natrix* (grass snake)) sampled within the Chernobyl Exclusion Zone (Ukraine).

MATERIALS AND METHODS

Site description and sampling

Over the seven year sampling period (2000 and 2007) samples of *L. agilis* and *N. natrix* were trapped at two sites: 'Red Forest' 1 and 'Red Forest' 2. A total of twenty *L. agilis* and five *N. natrix* were obtained (see Table 1). Site 'Red Forest' 1 was approximately 2.6 km south west from the Chernobyl NPP (E 30.06188, N 51.38427), and trapping occurred over a triangular area of *circa* 0.15 km^2. Site 'Red Forest' 2 was approximately 2.7 km south west from the Chernobyl NPP (E 30.06405, N 51.38095), and trapping occurred over a square shaped area of *circa* 0.01 km^2

Soil samples (0-10 cm) were available from measurement campaigns conducted by the Ukrainian co-authors: for 'Red Forest' 1, 345 soil cores were collected in June 2001 (Bondarkov *et al*. 2003) whereas for 'Red Forest' 2, four soil cores were collected in May 2007.

Analytical methods

Reptile samples were stored frozen, prior to analyses the gastrointestinal tract was removed and the remaining carcass washed. Soils were oven dried and homogenised prior to analyses.

Cs and Sr in reptiles

The whole-body ^{137}Cs and ^{90}Sr content in the reptiles was determined using the method described and validated by Bondarkov *et al*. (2002a;b). The animals were placed in a small, disposable, cardboard box (70x40x40 mm) the upper side of which was made from <0.1 mm thick polyethylene. The box was then placed inside a lead shielded counting container. The detectors comprised a hyper-pure germanium detector and thin-film (0.1 mm) NaI scintillation detector to measure ^{137}Cs and ^{90}Sr respectively. The ^{137}Cs spectra were analysed using the Genie-2000 software package. The activity concentration of ^{90}Sr was determined from that of its daughter nuclide, ^{90}Y.

Cs soils
Soil samples were analysed on hyper-pure (Canberra-Packard) germanium detectors to determine the activity concentration. Spectra were analysed using the Canberra-Packard Genie-2000 software package. Count times were such that an error of <20 % on the ^{40}K estimate was achieved.

Sr soils
Strontium-90 activity concentrations in soils were determined in sub-samples via the measurement of ^{90}Y activity concentrations using a thin-film (0.1 mm) NaI scintillation detector as described by Bondarkov *et al*. (2002a;b).

Pu reptiles
^{238}Pu and ^{239,240}Pu activity concentrations in reptiles were determined using standard radiochemical separation techniques and counted using a planar ion implanted silicon detector following co-precipitation on to a stainless-steel disc.

Pu soils
The $^{238/239/240}$Pu activity concentrations in soils were determined using the method described and validated by Bondarkov *et al*. (2002c). This method is based on measurement of the L_x - radiation (13-23 keV) emitted from excited uranium daughter isotopes following the α-decay of $^{238\text{-}240}$Pu. The method includes an absorption correction based on the self-absorption of K_x - radiation of barium (32-37 keV) which is a daughter isotope of ^{137}Cs.

RESULTS

Table 1 presents activity concentrations in soil samples. Table 2 presents activity concentrations determined in reptile samples. Note that although ^{238}Pu and $^{239/240}$Pu were measured separately, for comparison to soil results, these are reported as total $^{238/239/240}$Pu activity concentrations.

Table 1. Activity concentration (mean±SD) (kBq kg^{-1} (DW)) in 0-10 cm soil samples.

Site	n	^{137}*Cs*	^{90}*Sr*	$^{238/239/240}$*Pu*
'Red Forest' 1	345	1600 ±1420	780±660	27±39
'Red Forest' 2	4	1160±710	570±230	19±8.3
Izumrudnoe^{+}	29	7.7±3.6	n/a	n/a
Gluboky Lake^{+}	32	70±30	n/a	n/a

$^{+}$Unpublished data from additional sites within the Chernobyl Exclusion Zone (T.K. Oleksyk *pers. comm.*) (see discussion).

Table 2. Mean±SD whole-body fresh weight (FW) activity concentrations in reptiles (range in values is also presented).

Site	Sampling Date	Species	n	***^{137}Cs*** kBq kg^{-1}	***^{90}Sr*** kBq kg^{-1}	***$^{238/239/240}$Pu*** Bq kg^{-1}
'Red Forest' 1	Jul-Aug 2000	*Lacerta agilis*	2	610±540 230-990	360±180 230-490	3.5±1.0 2.8-4.3
'Red Forest' 1	May–Jul 2001	*Lacerta agilis*	8	480±250 180-950	500±320 69-1140	15±20 3.7-62
'Red Forest' 1	Aug 2003	*Lacerta agilis*	1	460	610	3.6
'Red Forest' 1	May 2007	*Natrix natrix*	2	290±240 120-450	140±61 92-180	1.6±1.8 0.28-2.8
'Red Forest' 2	May-Jul 2003	*Lacerta agilis*	9	870±410 140-1350	630±310 330-1300	6.2±8.4 0.89-28
'Red Forest' 2	May 2007	*Natrix natrix*	3	220±98 10-28	170±76 84-230	1.7±1.1 0.73-2.9
Izumrudnoe^{+}	Aug-Sep 1999	*Lacerta agilis*	10	4.0±2.9 1.7-12	n/a	n/a
Gluboky Lake^{+}	Aug-Sep 1999	*Lacerta agilis*	10	30±24 7.0-73	n/a	n/a

$^{+}$ Unpublished data from additional sites within the Chernobyl Exclusion Zone (T.K. Oleksyk *pers. comm.*) (see discussion).

DISCUSSION

In addition to the results from the sampling described here, Table 2 presents whole-body ^{137}Cs activity concentrations for *L. agilis* from two additional sites within the Chernobyl Exclusion Zone (Table 1 includes data for these sites; T.K. Oleksyk *pers. comm.*). Many of the assessment models derived to estimate the exposure of wildlife to ionising radiation use concentration ratios (CR) to estimate whole-body activity concentrations in organisms from those in soil (or other media), where CR is defined as:

$$CR = \frac{Activity\ concentration\ in\ biota\ whole\text{-}body\ (Bq\ kg^{-1}\ FW)}{Activity\ concentration\ in\ soil\ (Bq\ kg^{-1}\ DW)}$$

Table 3 presents estimated CR values for ^{137}Cs, ^{90}Sr and $^{238/239/240}$Pu to *L. agilis* and *N. natrix* sampled as part of this study. Values for ^{137}Cs for the *L. agilis* samples from Izumrudnoe and Gluboky Lake have also been estimated; the values are similar to those calculated for 'Red Forest' 1 and 2.

Table 3 also includes default CR values (including ranges) from the ERICA Tool. The values derived here for ^{137}Cs are within the range of those in the ERICA database, although *circa* one-order of magnitude lower than the default value. However, the ERICA default is highly skewed by one measurement (in-house data) of *L. agilis* (CR=28) from the Chernobyl Exclusion Zone. The values estimated here are more in agreement with those for *Lacerta vivipara* and *Anguis fragilis* from the coastal sand dune study of Wood *et al*. (in press) which constitute the remaining values in the ERICA database. The same two data sources were used to derive the ERICA Tool ^{90}Sr default CR; the only available data were a value of 0.008 for *A. fragilis* and 47 for *L. agilis*. The ERICA-Tool default CR value for Pu for reptiles is assumed to be the same as that for mammals (see Table 3). The Pu CR values derived in this work are 2-3 orders of magnitude lower than the ERICA mammal value and at the lower end of the range in CR values for mammals (see Table 3). Consideration will be given to altering the ERICA-Tool database for reptile to include the values reported here.

Table 3. CR values for reptiles (Mean±SD). For comparison default CR values from the ERICA-Tool for mammals and reptiles are presented.

Site	Sampling Date	Species	n	^{137}Cs	^{90}Sr	$^{238/239/240}Pu$
'Red Forest' 1	Jul.–Aug. 2000	*Lacerta agilis*	2	0.389±0.488	0.470±0.461	$(1.28\pm1.83)x10^{-4}$
'Red Forest' 1	May–Jul 2001	*Lacerta agilis*	8	0.300±0.309	0.642±0.682	$(5.48\pm10.5)x10^{-4}$
'Red Forest' 1	Aug. 2003	*Lacerta agilis*	1	0.275	0.740	$1.32x10^{-4}$
'Red Forest' 1	May 2007	*Natrix natrix*	2	0.156±0.19	0.150±0.144	$(5.69\pm10.3)\ x10^{-5}$
'Red Forest' 2	May–Jul 2003	*Lacerta agilis*	9	0.815±0.625	1.21±0.764	$(3.24\pm4.66)x10^{-4}$
'Red Forest' 2	May 2007	*Natrix natrix*	3	0.187±0.142	0.296±0.177	$(8.83\pm7.02)x10^{-5}$
Izumrudnoe	Aug-Sep 1999	*Lacerta agilis*	10	0.512±0.373	-	-
Gluboky Lake	Aug-Sep 1999	*Lacerta agilis*	10	0.431±0.346	-	-
ERICA-Tool (range)	n/a	Reptile	n/a	3.59±9.91 0.06-28.1	11.8±23.5 0.008-47	n/a^{+}
ERICA-Tool (range)	n/a	Mammals	n/a	2.87±4.25 0.001-137	1.74±2.35 0.001-11.9	$(2.34\pm8.13)x10^{-2}$ $4.53x10^{-4}$-$3.17x10^{-1}$

$^{+}$The default ERICA-Tool CR for Pu to reptiles is assumed to be the same as for mammals.

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