Biological half-life

The rates of uptake and loss of radionuclides varies between animals and tissues. The rate of loss of a radionuclide from an animal (or specific tissues and milk) once it has been removed from a contaminated diet, is termed the biological half-live ($T_{1/2b}$). This is defined as the time required for the radionuclide activity concentration in a given tissue (whole-body or milk) to be reduced by one half excluding physical decay. For some radionuclides, (e.g. radiocaesium, ^{3}H, ^{14}C) $T_{1/2b}$ seems to be associated with the metabolic turnover rate. For others, it is controlled by stable element status, for instance, radiostrontium is released at an enhanced rate from bone during periods of calcium deficiency (e.g. peak lactation in dairy animals). For most radionuclides the major excretion routes of radionuclides from an animal are faeces and urine. The relative importance of each excretion route varies for different radionuclides although it can be influenced by stable/analogous element status.

The biological half-life of radionuclides in animals is an important factor influencing the effectiveness and practicalities of many countermeasures targeting animal derived foodstuffs (i.e. clean feeding, change of grazing regime, or additive based countermeasures).

Although often a single value of biological half-life is given for an animal (or tissue) the dynamics of loss are generally multi-compartment; short-term loss being determined by rapidly turning over pools and longer-term loss by the dynamics of the radionuclide in the major storage organ(s) (e.g. the rate of loss of ^{110m}Ag from all the bodies tissues reflects that from the liver, see Table 1). To give an example of biological half-lives for different radionuclides and tissues Table 1 compares values for a variety of sheep tissues.

The rate of decline of radionuclide activity concentrations in milk is rapid. Reported half-lives (for the short term and dominant component of loss) for Sr, I and Cs in different species of dairy ruminants are all in the range 0.5-3.5 days (e.g. Kahn *et al*. 1965; Sirotkin *et al*. 1969; Howard et al. 1993; Fabbri *et al*. 1994).

In many cases, smaller animals have a more rapid turnover of radionuclides than large animals. From the observations of Stara *et al*. (1971), Coughtrey *et al*. (1983a) proposed weight dependent relationships for (i) hens and (ii) ruminants and pigs (see Table 2). These differences are probably related to the higher metabolic rates of small compared to large animals. More recently weight dependent (or allometric) relationships for the long component of $T_{1/2b}$ for a range of radionuclides in animals (for the purposes of modelling transfer to wild species) have been derived (USDOE 2002; Higley *et al*. 2003; Brown *et al*. 2003) where:

$$T_{1/2b} = a(\text{live-weight})^{b}$$

Values of the constants *a* and *b* are presented in Table 2. Other reviews have concluded that there is no live-weight dependence for some of these radionuclides (e.g. see series of reviews by Coughtrey *et al*. list below).

There are relatively few data describing the rate of loss from animals of many of the radionuclides considered within EURANOS. For some of the radionuclides considered (e.g. Pu, Am, Ce) the $T_{1/2b}$ is sufficiently long that clean feeding is unlikely to be feasible if activity concentrations exceed intervention limits. However, many of these radionuclides are largely accumulated in tissues other than meat (e.g. liver and bone) (see Table 3). It may therefore be more practicable to prevent entry of the target organ into the foodchain whilst allowing the consumption of less contaminated meat (i.e. muscle).

Table 1. Biological half-lives for different radionuclides in sheep tissues; where two half-lives are given (e.g. Ce in muscle) they represent values for two components of loss, the numbers in parenthesis are the percentage of total radioisotope excreted with that half-life.

Radionuclide	Tissue	Biological half-life (d)	Reference
Ag	Liver	46	Beresford *et al*. (1998a)
Ag	Muscle	4.6 (21%); 47 (79%)	Beresford *et al*. (1998a)
Ce	Bone	2050	Beresford *et al*. (1998a)
Ce	Muscle	69 (40%); 1350 (60%)	Beresford *et al*. (1998a)
Co*	Liver	61	Beresford *et al*. (1996)
Co*	Muscle	77	Beresford *et al*. (1996)
Cs	Milk	1.5 (53 %); 6.9 (43%)	Assimakopoulos *et al*. (1989)
Cs	Meat	35+	Assimakopoulos *et al*. (1993)
Cs	Meat	9.8++	Beresford *et al*. (1998b)
I	Milk	1	Howard *et al*. (1993)
Pu	Liver	135	Buldakov *et al*. (1970)
Ru	Kidney	3.9 (56 %); 36 (44 %)	Beresford *et al*. (1998a)
Ru	Muscle	42	Beresford *et al*. (1998a)

* Administered as inorganic Co
\+ Boutsiko ewes 84 kg
++ Swaledale/Herdwick ewes 44 kg

Table 2 Parameters for allometric relationships describing the biological half-life of a range of radionuclides in animals.

Radionuclide	*a*	*b*	Reference
Am	1140	0.73	Brown *et al*. (2003)
Ce	352	0.8	USDoE (2002)
Cl	2.38	0.25	Brown *et al*. (2003)
Cm	1140	0.73	Brown *et al*. (2003)
Co	13.6	0.24	USDoE (2002)
Cs (ruminants & pigs)	5.18	0.3	Coughtrey *et al*. (1983a)
Cs (hens)	22.3	0.325	Coughtrey *et al*. (1983a)
I	16.7	0.13	Higley *et al*. (2003)
Pu	1140	0.73	Brown *et al*. (2003)
Ra	277	0.28	USDoE (2002)
Sb	2.8	0.25	USDoE (2002)
Sr	645	0.26	Higley *et al*. (2003)
Tc	4.8	0.4	USDoE (2002)
Th	888	0.8	USDoE (2002)
U	5.5	0.28	USDoE (2002)
Zr	562	0.25	USDoE (2002)

Table 3. Target organs for a range of potentially important radionuclides.

Radionuclide	Target organ	References
Ag	Liver	Beresford *et al*. (1998a)
Am	Bone and liver	Coughtrey et al. (1984a)
Ce	Bone and liver	Beresford *et al* (1998a)
Co*	Liver	Voigt (1988)
Cs	All soft tissue and milk	Coughtrey *et al*. (1983a)
I	Thyroid and milk	Lengemann *et al*. (1974)
Pu	Bone and liver	Coughtrey *et al*. (1984b)
Ru	Kidney	Beresford *et al*. (1998a)
Sr	Bone and milk	Lengemann *et al*. (1974)
Tc	Thyroid, liver & stomach wall	Coughtrey et al. (1983)

*Co-Vitamin B12

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