New detectors for live-monitoring of radionuclides in wildlife

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1. Why are new methods needed?

- Assessments required by International Commission on Radiological Protection (ICRP) 2007 recommendations and EC Birds and Habitats Directives (for protected species).
- Current methods for assessments involve conservative modelling and destructive measurement techniques.
- Growing interest in non-lethal monitoring techniques such as live-monitoring as many species needing assessment are protected.
- Previous live-monitoring has typically focused on only a small number of radionuclides and predominantly domesticated/semi-domesticated animals.

2. Aim

Project aims to develop new methods and technologies for measuring radionuclide activity concentrations in wildlife, without the need to destroy the target organism. The following displays the progress towards setting out the development criteria for a live-monitoring system to be used in a regulatory context.

3. Methods

- Selection of target radionuclide based on review of radionuclide monitoring reports (RIFE) and frequency of appearance in journal articles for measurement radionuclides in wildlife. Decay probabilities reported for emission energies above 50 keV.
- Penetration range of radiation through tissue calculated for beta and gamma (alpha range not reported due to negligible range)

  Beta range (mm):

$$\mathbf{R \approx 4.12E^{1.265-0.0954lnE}} \quad \text{(For E < 2.5 MeV)}$$

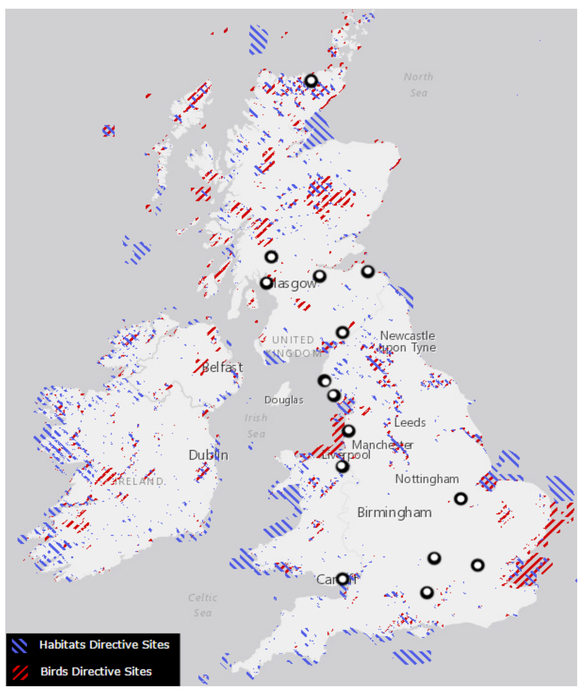
  Gamma half value thickness (mm):

$$\boldsymbol{I = I_0 e^{-\left(\frac{\mu}{\rho}\right)\rho R}}$$

  (*Note: Tissue properties based on human tissue*)

- Radionuclide activity concentration trigger levels (for exceeding 10µGy/h screening dose rate) calculated for terrestrial RAP groups; amphibian, bird, large mammal, small mammal, and reptile.
  - Soil radionuclide activity concentration measurements used from RIFE. Measurements reported as below the limit of detection were halved.
  - ERICA database utilised to calculate expected activity concentrations (Bq/kg) in wildlife from radionuclide soil concentrations. Default ERICA radiation weightings were used.

4. Radionuclides to monitor



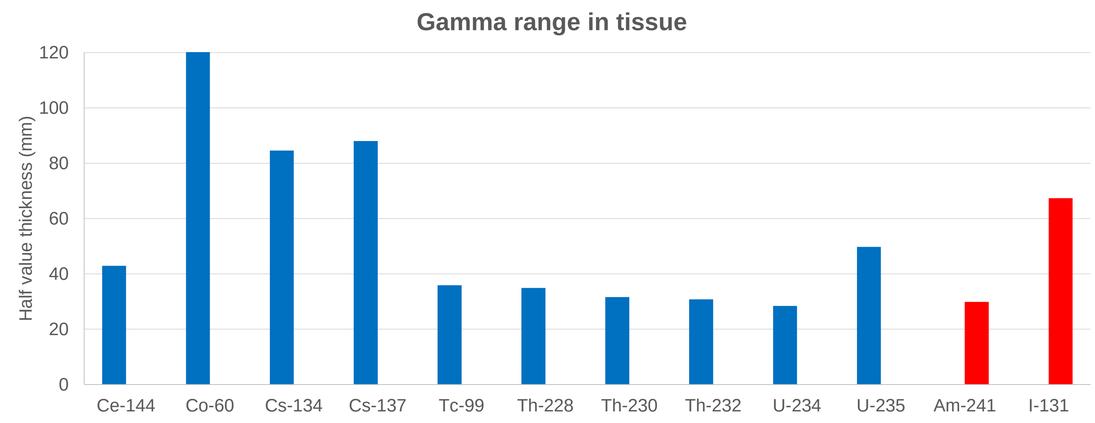
Significant sites where radionuclide emissions are monitored in RIFE (black circles).

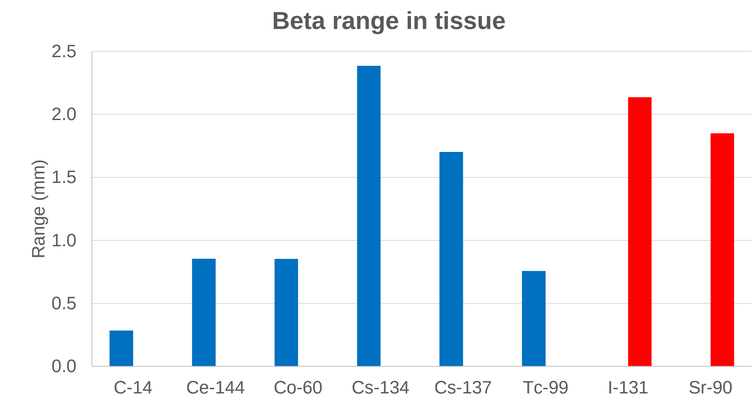
Nuclide	Decay probability of most abundant energy peak per 100 emissions (%)		
	Alpha	Beta	Gamma
Am-241	85.00		35.90
C-14		100.00	
Ce-144		76.50	11.09
Co-60		99.88	&99.98
Cs-134		70.17	97.62
Cs-137		94.70	85.10
H-3		*100.00	
I-131		89.60	81.50
Pu-238	100.00		
Pu-239	70.80		
Pu-240	72.8		
Sr-90		100.00	
Tc-99		100.00	0.00
Th-228	72.2		1.19
Th-230	76.3		0.38
Th-232	78.2		0.26
U-234	71.40		0.12
U-235	57.70		57.03
U-238	79.00		

List of radionuclides of monitoring interest for terrestrial pathways.
**Energy <50 keV. Included to indicate decay mode*
&second energy peak of similar probability present

5. Detection of radionuclides in living organisms

Range in tissue for radiation from targeted radionuclides. Half value thickness (mm) reported for gamma. Maximum range reported for beta (mm).

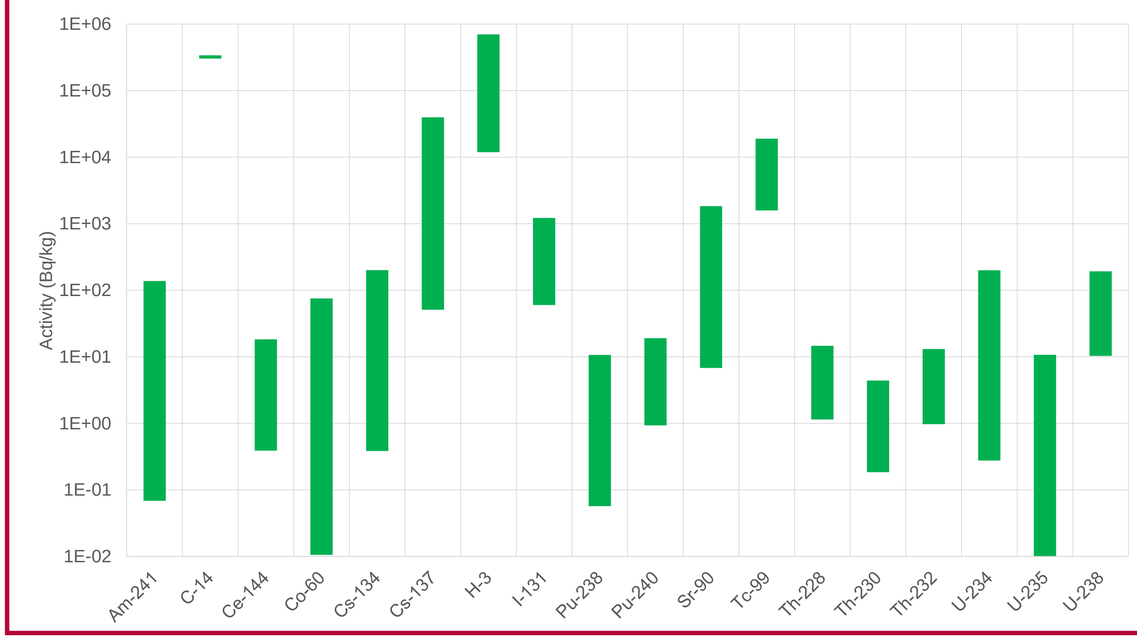




Radionuclides that accumulate either fully or in part whole body **(BLUE)**. Radionuclides that accumulate only within bones or internal organs **(RED)**

6. Activity levels

Maximum and minimum radionuclide activity concentration (Bq/kg) required to trigger 10µGy/h screening dose rate in a range of terrestrial animals



7. Discussion and further work

Radionuclides detectable by gamma emissions

- ^{241}Am, ^{134}Cs, ^{137}Cs, and ^{131}I - large decay probabilities and range in tissue. Large activity concentration trigger level.
- ^{144}Ce and ^{235}U may be measureable as large decay probability and range in tissue, but have a low trigger level so may not be distinguishable from background.

Radionuclides detectable by beta emissions

- ^{14}C, ^{60}Co, ^{90}Sr, and ^{99}Tc - large decay probabilities and activity trigger level.

Radionuclides not detectable by gamma or beta emissions:

- ^{3}H decay energy below 50 keV.
- Gamma decay probability in Th isotopes and ^{234}U low. Activity trigger level for Th isotopes low. Reliance placed on alpha emission.
- Pu isotopes and ^{238}U - alpha decay only.

Next steps:

- Check alternative routes for detection of radionuclides. E.g. ^{90}Y often used to estimate ^{90}Sr as ^{90}Y has greater range in tissue.
- Assessment of activity concentration trigger levels against background levels to define live-monitoring system specification (minimum measurable activity and dimensions of detector).

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