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).
  \[ R = 4.12 \times 10^{3} \frac{d}{\alpha} \text{ (For } E < 2.5 \text{ MeV)} \]
  \( \Gamma \) half value thickness (mm):
  \[ I = \frac{1}{2} e^{-\frac{d}{\Gamma}} \]
  (Note: Tissue properties based on human tissue).
• Radionuclide activity concentration trigger levels (for exceeding 10µSv/h screening dose rate) calculated for terrestrial RAP groups: amphibian, bird, large mammal, small mammal, reptile.
  o Soil radionuclide activity concentration measurements used from RIFE. Measurements reported as below the limit of detection were halved.
  o 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

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>Decay probability of most abundant energy peak per 100 emissions (%)</th>
<th>Alpha</th>
<th>Beta</th>
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<tbody>
<tr>
<td>Am-241</td>
<td>85.00</td>
<td>100.00</td>
<td>55.00</td>
</tr>
<tr>
<td>C-14</td>
<td>100.00</td>
<td>76.50</td>
<td>11.09</td>
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<td>Co-60</td>
<td>99.18</td>
<td>70.17</td>
<td>97.62</td>
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<tr>
<td>Co-57</td>
<td>94.70</td>
<td>94.10</td>
<td>85.10</td>
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<tr>
<td>H-3</td>
<td>100.00</td>
<td>100.00</td>
<td>81.50</td>
</tr>
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<td>I-131</td>
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<td>72.8</td>
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<tr>
<td>Cs-134</td>
<td>100.00</td>
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<td>Th-228</td>
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<td>U-235</td>
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<td>79.00</td>
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</tr>
<tr>
<td>U-238</td>
<td></td>
<td>79.00</td>
<td></td>
</tr>
</tbody>
</table>

List of radionuclides of monitoring interest for terrestrial pathways.
*Energy <50 keV. Indicated to indicate decay mode a 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).

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

7. Discussion and further work
Radionuclides detectable by gamma emissions
• ²³⁴U, ²³⁵U, ²³⁷Np, and ²³⁹Pu - radionuclides detectable by gamma emission.
  \( \beta^{+} \) decay energy below 50 keV
  Pu isotopes and ²³⁹Pu - alpha decay only.

Radionuclides detectable by beta emissions
• ²³⁸Pu, ²³⁹Pu, and ²³⁹Th - large decay probabilities and activity trigger level.

Radionuclides not detectable by gamma or beta emissions:
• ²³⁹Pu, ²³⁹Ac, ²³⁹Th, and ²³⁹Pu - large decay probabilities and range in tissue. Large activity concentration trigger level.

Next steps:
• Check alternative routes for detection of radionuclides. E.g. ¹³⁷Cs often used to estimate ¹³⁷Cs as ²³⁹Pu 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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