Self-attenuation in the low-energy range: an experimental study on ^{210}Pb

ON-GOING EXERCISE OF THE ICRM GAMMA SPECTROMETRY WORKING GROUP

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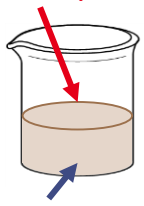
Motivation: Quantitative analyses of environmental samples generally involve volume sources with low radioactivity and unknown composition of the sample matrix. Unless an efficiency calibration with the same geometry and matrix is available, it is necessary to correct the raw counting rates for self-attenuation effects in order to obtain the true sample activity.

This exercise examines the different steps required to calculate the final activity of unknown matrices, based on the calibration obtained with a reference matrix, in the same geometry. This includes: measurement of the linear attenuation coefficients, calculation of self-attenuations (between void and solid sample) and self attenuation corrective factors (between reference and unknown matrices).

At LNHB, preparation of
3 samples with different densities
1 sample used as reference for calibration (known activity)

Radionuclides (^{210}Pb and ^{137}Cs)



Epoxy polymer: reference

2 samples (A and B) with unknown activity

4 batches circulating between 12 laboratories

For each matrix, one blank sample, one sample with ^{137}Cs + ^{210}Pb

^{137}Cs acts as reference (weak attenuation) while ^{210}Pb is a difficult case (strong attenuation)

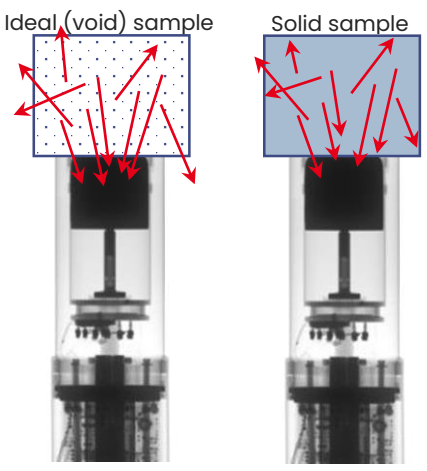
In each participating laboratory

Measurement and or calculation of linear attenuation coefficients μ/ρ (cm^{-1})

Detection efficiency calibration
for the two energies of interest
using the reference matrix

Self-attenuation effect:

The number of exiting photons is lower than the number of emitted photons



HPGe detector

Depends on the source-detector geometry and photons energy

Measurement of the 2 samples with unknown matrices (A and B)

Calculation of the self-attenuation corrective factors (between reference and unknown matrices) (Efficiency transfer factors)

Determination of the activities of ^{137}Cs and ^{210}Pb included in samples A and B

Reference date: 1st October 2022 – 12:00:00 UTC

	Half-life (a)	Photon emission energy (keV)	Photon emission intensity (%)
^{210}Pb	22.23 (12)	46.5	4.252 (40)
^{137}Cs	30.05 (8)	661.7	84.99 (20)

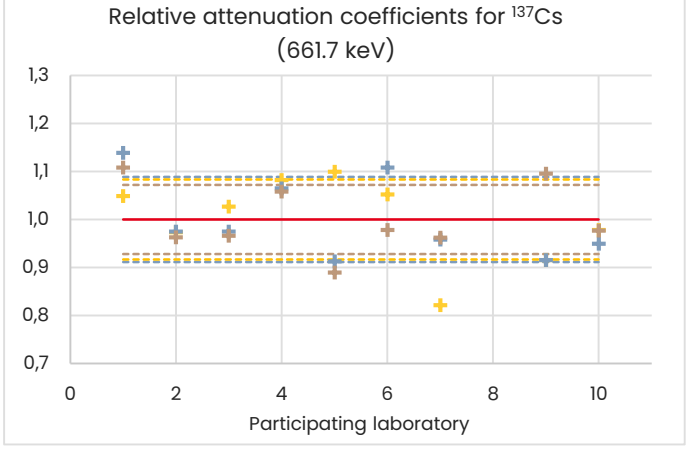
Preliminary results:

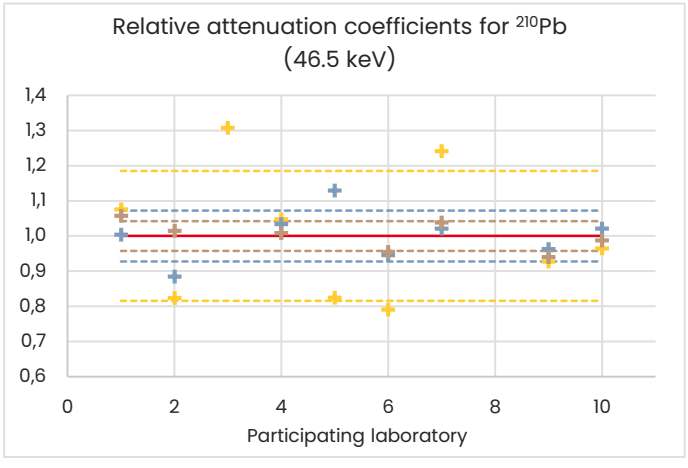
- Each participant had to provide a report with detailed measurement procedure:
  - detector characteristics;
  - measurement geometry (source-detector distance);
  - reference efficiencies (46.5 keV and 661.7 keV);
  - peak shape (^{210}Pb) – influence of scattered photons in the left side of the peak.
- Measurement of linear attenuation coefficients of the 3 matrices:
  - Procedure and results for the 3 matrices and 2 energies (46.5 keV and 661.7 keV).

Conclusion: Unexpected large differences that highlight the value of such a study.
Analysis of the different experimental approaches on going.

Next steps:

- After checking of the first results, next steps will consist in:
  - calculation of self-attenuation (matrix/vacuum) and self-attenuation corrective factors (unknown matrix/reference matrix), procedure (method, software, approximation, etc.), results for the 3 matrices and 2 energies.
- Final results: activity (^{210}Pb and ^{137}Cs) of samples A and B with associated uncertainty budget.
- **Final objective: provide recommendations for gamma spectrometry with unknown matrix in the low-energy range.**





+ Reference, + Matrix A, + Matrix B

^{137}Cs	Ref	A	B
Relative standard deviation (%)	8.8	8.3	7.2

First step and already interesting results and material for discussion

^{210}Pb	Ref	A	B
Relative standard deviation (%)	18.5	7.2	4.5