Implementation of efficiency transfer, and methods for corrections of systematic effects in gamma spectrometry

Sofia Jonsson
Henrik Ramebäck

Overview

- Background
- Aim
- Approach
- Results
- Conclusions

Background

- TCS affected calibrations
- Density and volume corrections at 661 keV
- Limited to the validated calibration geometries

Aim

- Establish a coincidence free end-cap calibration
- Improve the knowledge and capacity to correct for
  - True coincidence summing (TCS)
  - Matrix and densities
  - Volumes
  - Geometries
- Explore four different calculation codes
  - ANGLE
  - GESPECOR
  - EFFTRAN
  - VGSL

Input parameters

- Detector parameters
- Container
- Volume
- Source/sample, matrix/density
- Geometry

Approach

1. Establishment of coincidence free end-cap calibration
2. Validation of the calibration (nuclides without TCS)
3. Validation of TCS-corrections in the calibration geometry (3 codes)
4. Volume corrections (4 codes)
5. Geometry corrections (4 codes)
6. Density corrections (4 codes)

1. Establishment calibration

- Ultra low-background (ULB) p-type coaxial high-purity germanium (HPGe) detector
- Relative efficiency, 80%
- GammaVision version 6.01
- Reference solution, QCYA 8163
  - Am-241, Cd-109, Co-57, Co-57, Ce-139, Hg-203, Sn-113, Sr-85, Cs-137, Mn-54, Zn-65, Co-60, Y-88

cont. 1. Establishment of calibration

- 60 mL plastic container
- Calibration source, water solution, density 1g/cm^3
- Geometry: 60mL UltraNear – end cap placement

cont. 1. Establishment of calibration

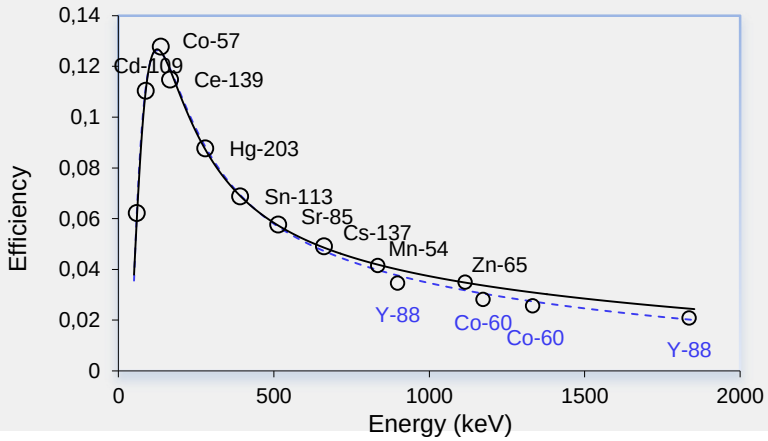
Energy calibration
59-1836 keV

Empirical efficiency calibration between
59-1116 keV

Optimisation of detector parameters
(VGSL)

TCS corrections,
Co-60 and Y-88

Semi-empiric calibration
60UN
59-1836keV



2. Validation of the calibration

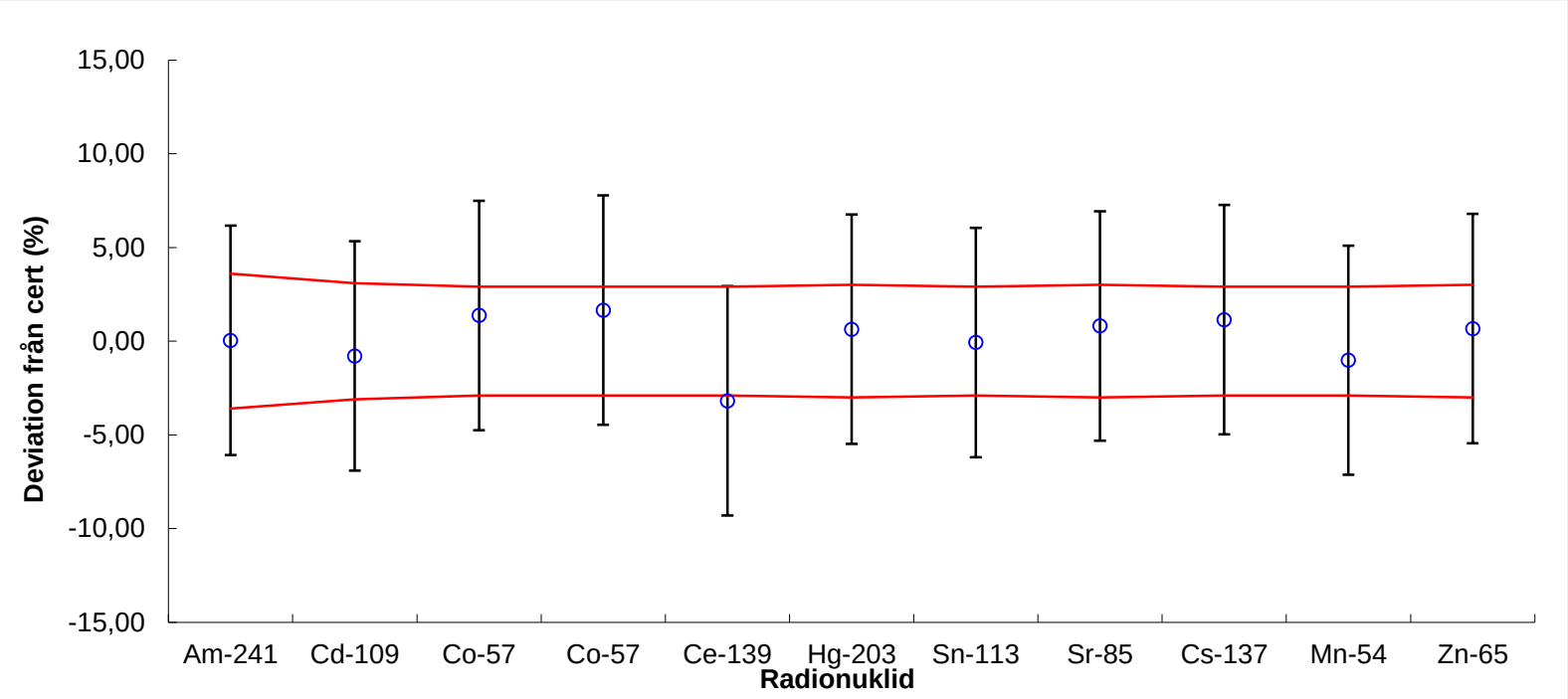


Figure 1. Activity determination of nuclides without TCS in the calibration solution

3. Validation of TCS-corrections in the calibration geometry

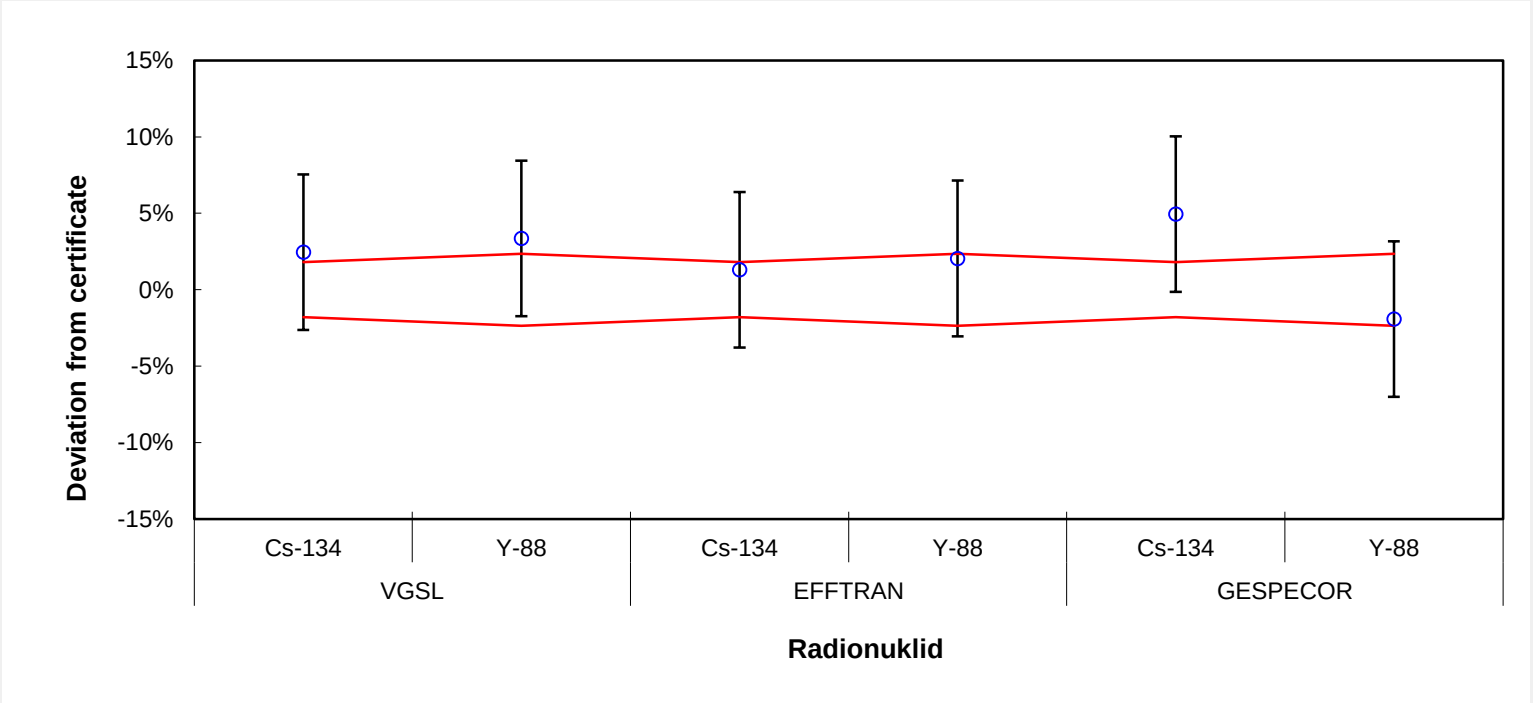


Figure 2. Validation of TCS corrections with VGSL, EFFTRAN and GESPECOR in a TCS mix

4. Volume corrections

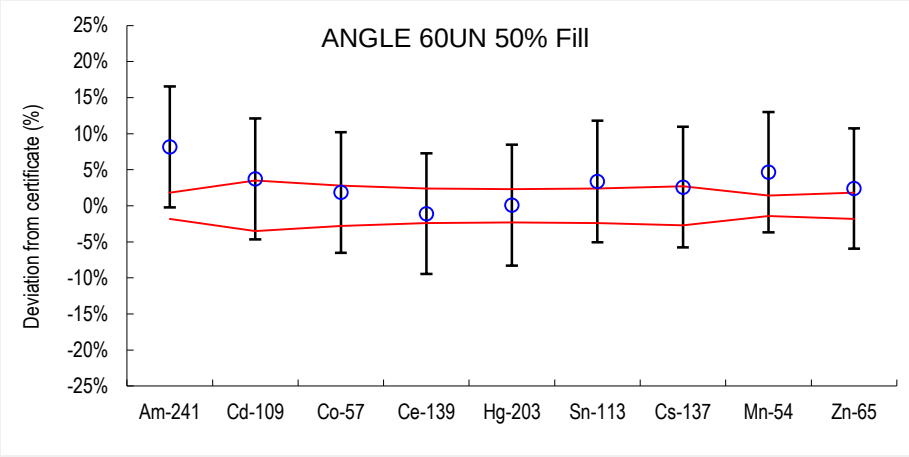
- New reference solution (TCS mix), QCYA 18187
  - Am-241, Cd-109, Co-57, Co-57, Ce-139, Hg-203, Sn-113, Cs-134, Cs-137, Mn-54, Zn-65, Y-88
- Reference calibration 60UN
- 60 ml container
  - 50% fill
  - 25% fill

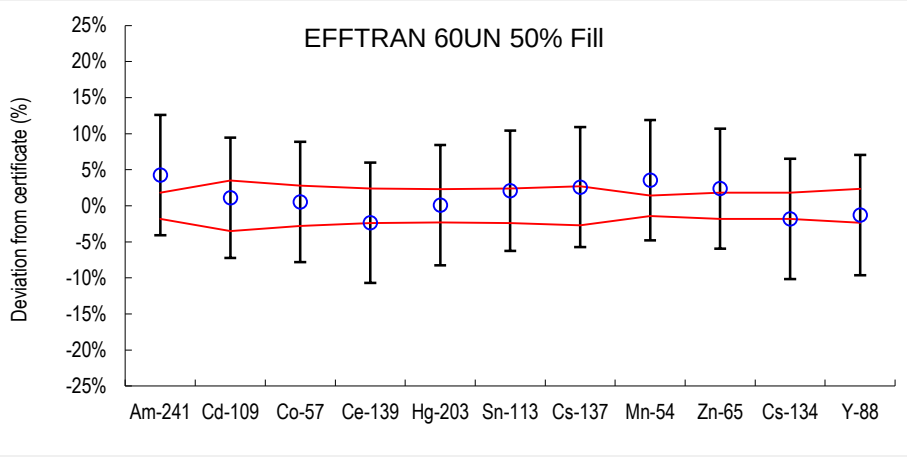
Estimation of the uncertainty of volume corrections

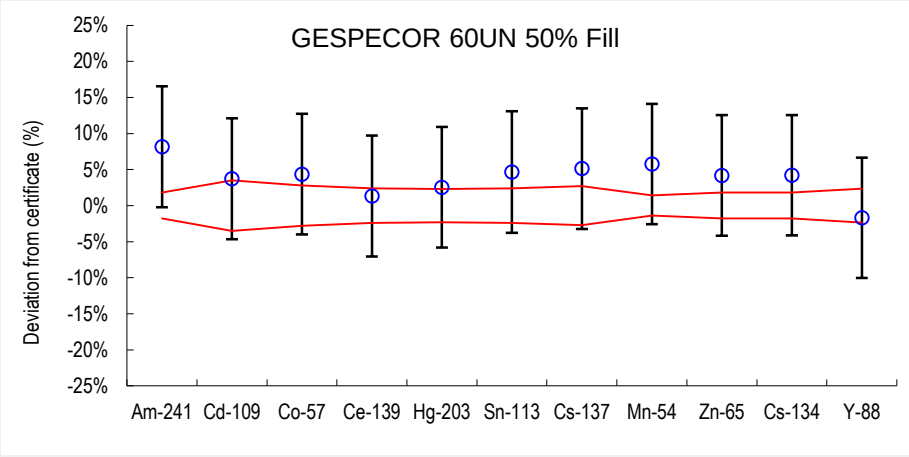
- Measurement of the volume (by height)
- Filling degree of 25 was measured to 4 mm $\pm$ 1
- Simulation of efficiency curves for 3, 4 and 5 mm
- Unc. volume correction was set to 3.5%
- The total uncertainty of the correction is most likely a bit higher

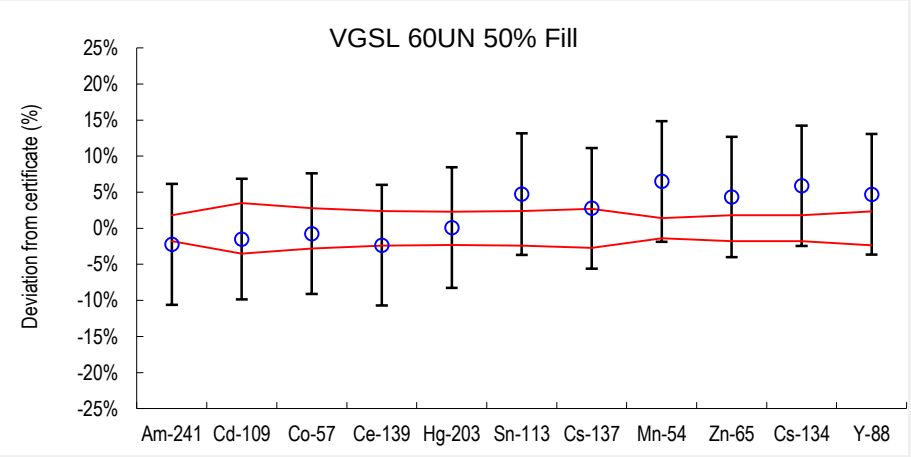
cont. 4. Volume corrections

60mL container 50% filling









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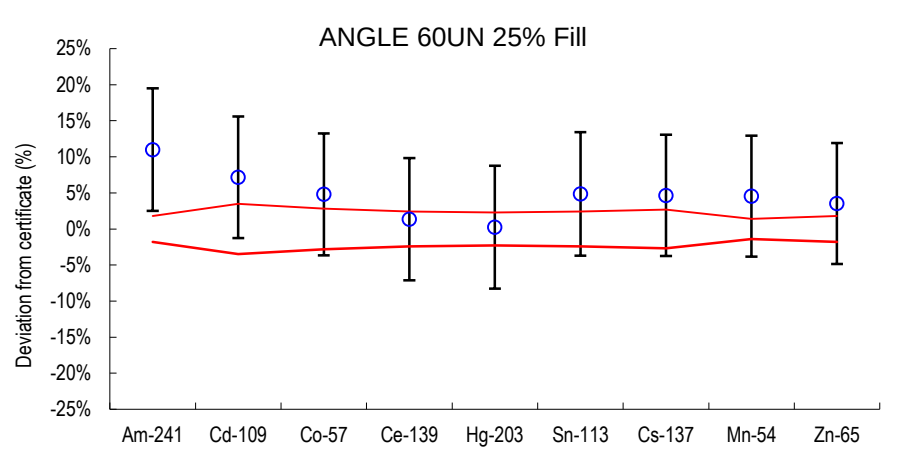
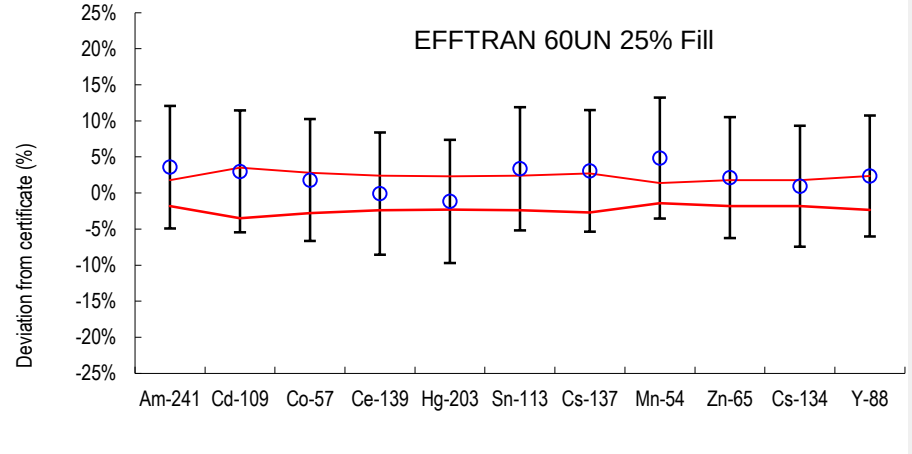
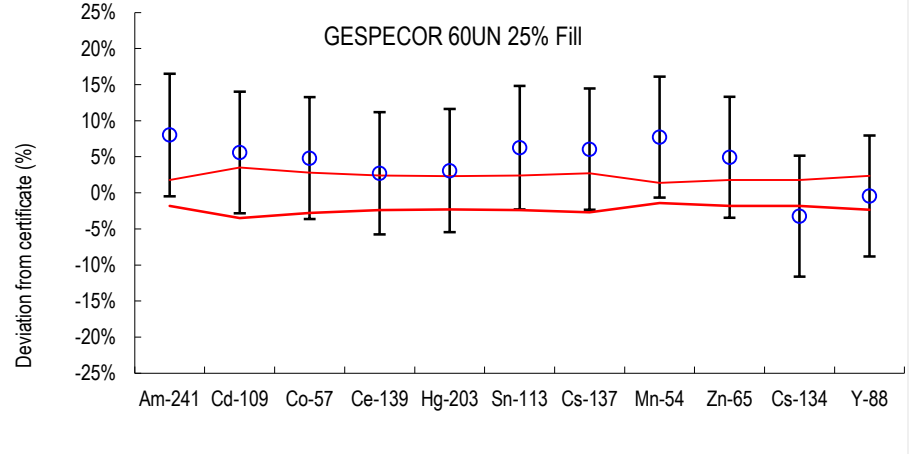
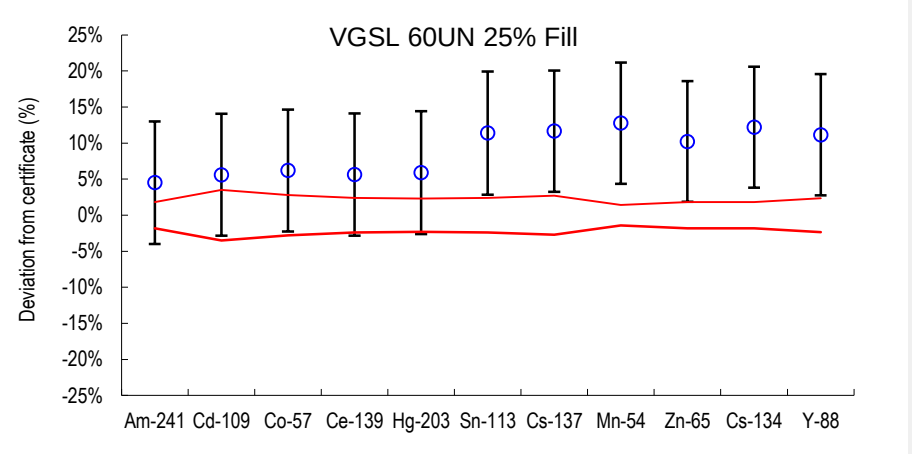
cont. 4. Volume corrections

60mL container 25% filling









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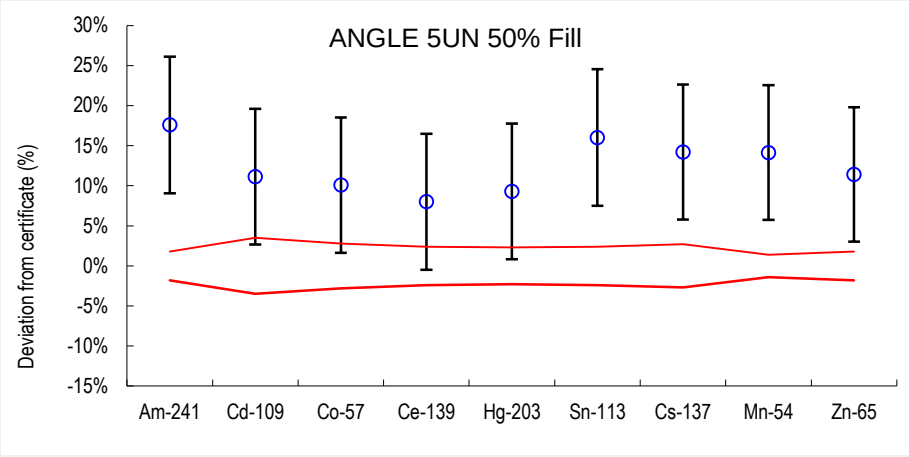
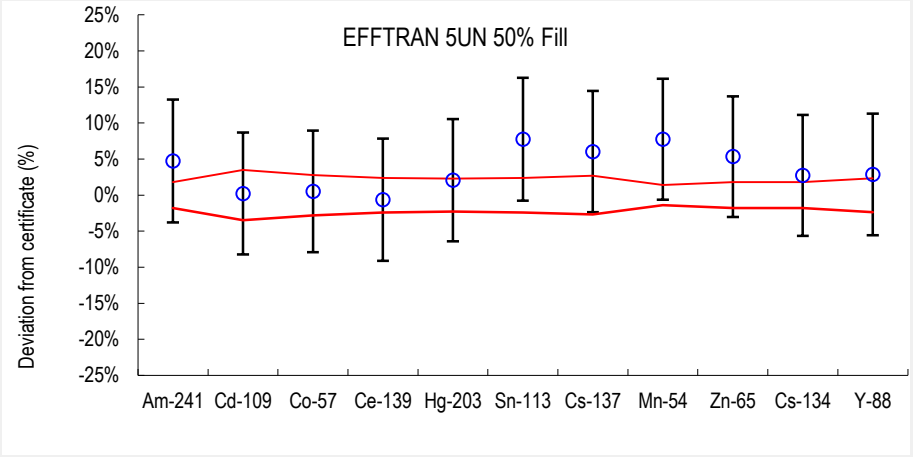
5. Geometry corrections

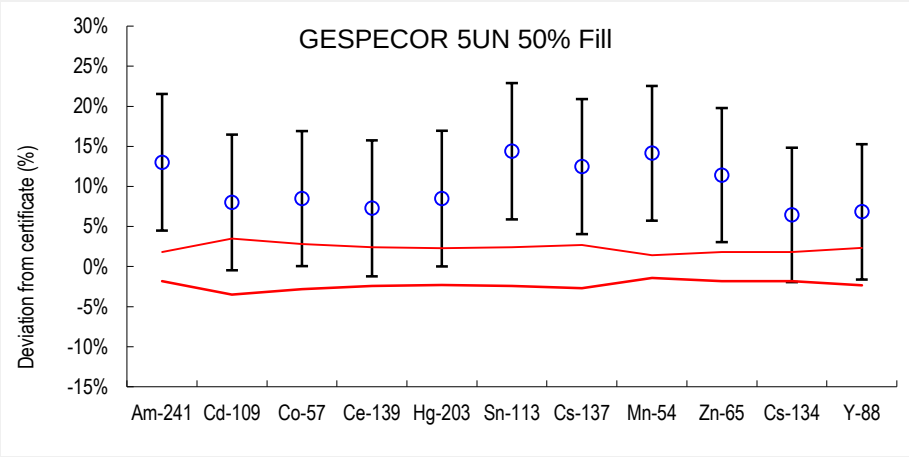
- TCC mix QCYA 18187
- Reference calibration 60UN
- End cap placement of container
- 5 mL container
  - 50% fill
- 200 mL container
- Uncertainty of correction factor is set to 3.5

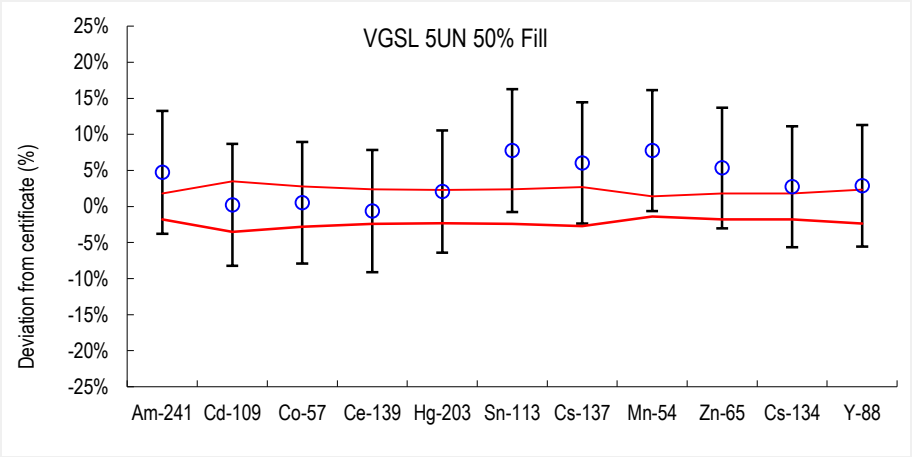
cont. 5. Geometry corrections

5mL









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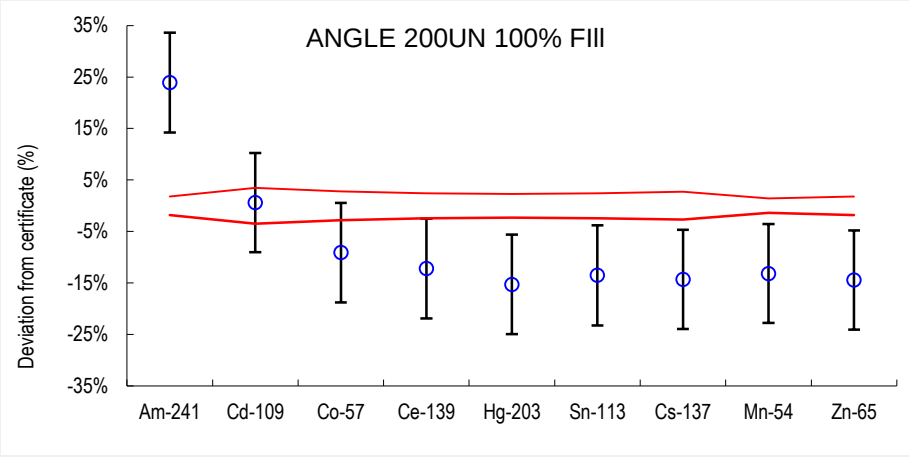
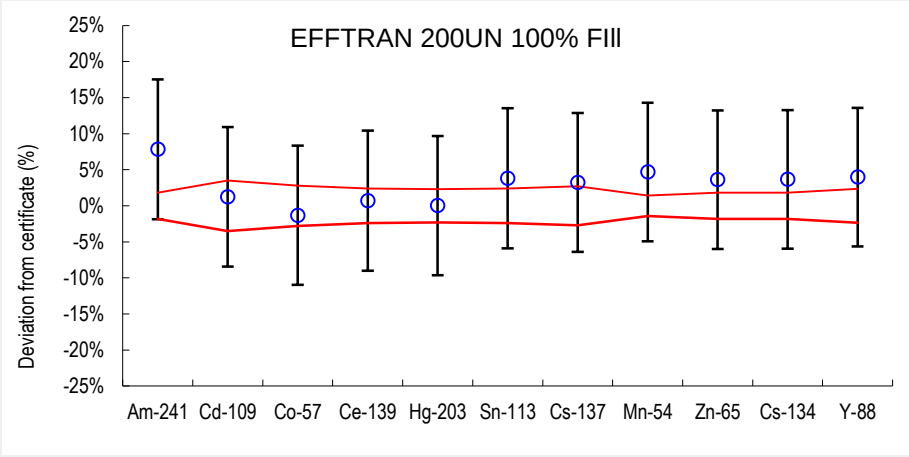
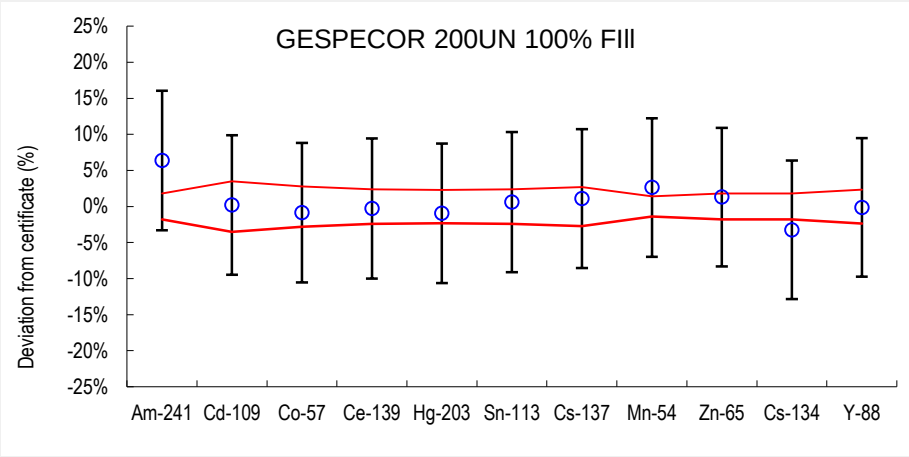
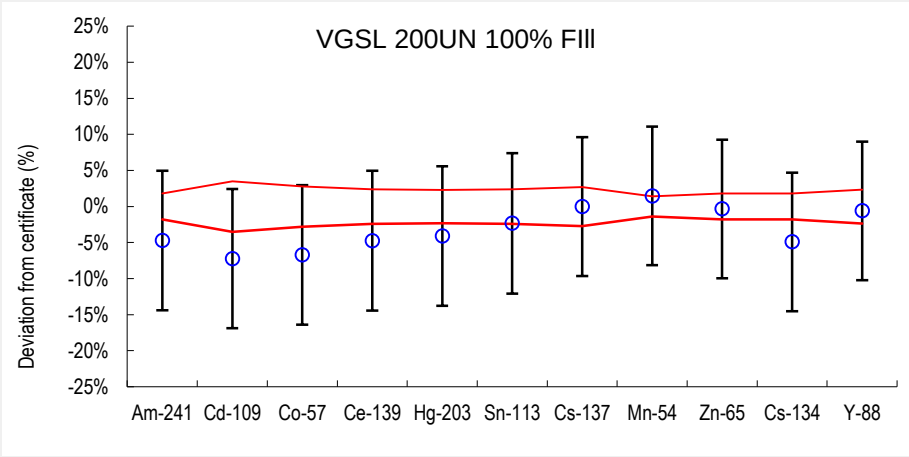
cont. 5. Geometry corrections
200mL









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6. Density and matrix corrections

- Four reference materials were analysed
- Corrections from the four calculation codes were calculated for densities
- Small differences for No1-3 between density corrected and uncorrected values

No	Reference material	Matrix	Density	Geometry	Nuclides
1	IAEA 154	Whey	0.63	60UN (100%)	Cs-137 K-40
2	IAEA 373	Grass	0.33	60UN (100%)	Cs-137 K-40
3	IAEA 447	Soil	0.81	60UN (100%)	Cs-137 K-40
4	IAEA 135	Soil	0.98	60UN (25%)	Am-241 Cs-137 K-40

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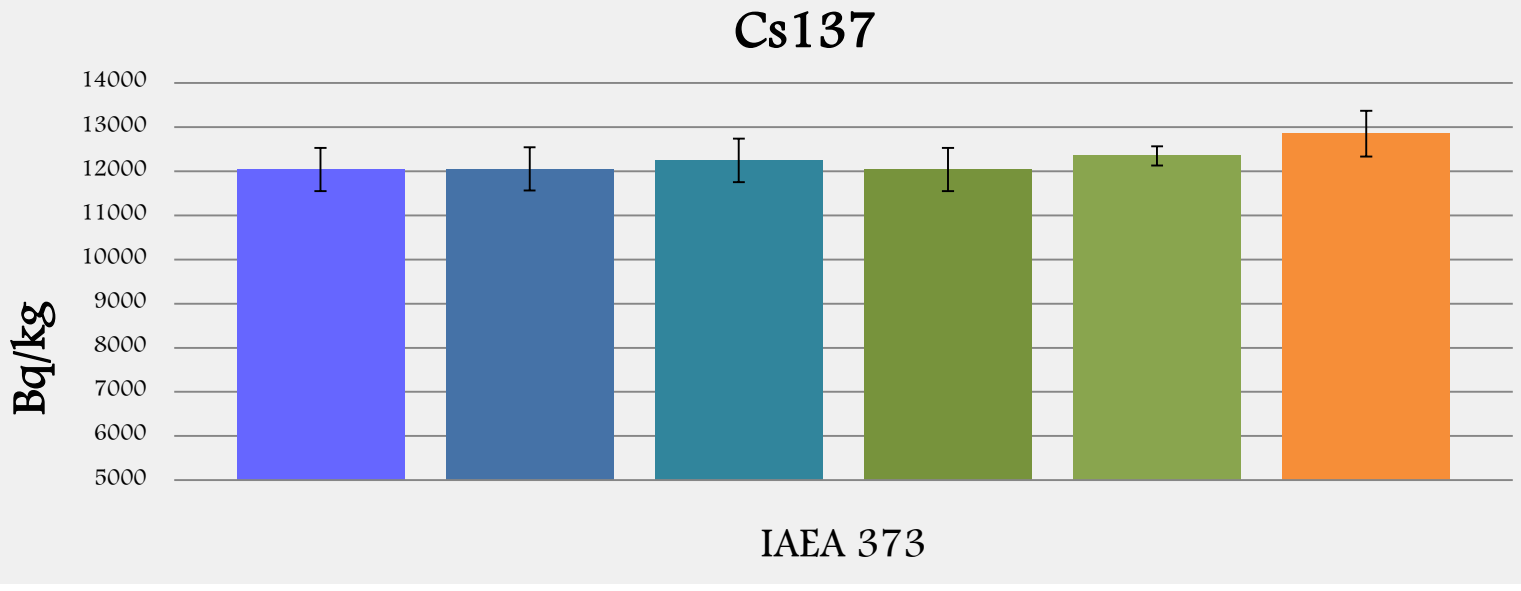
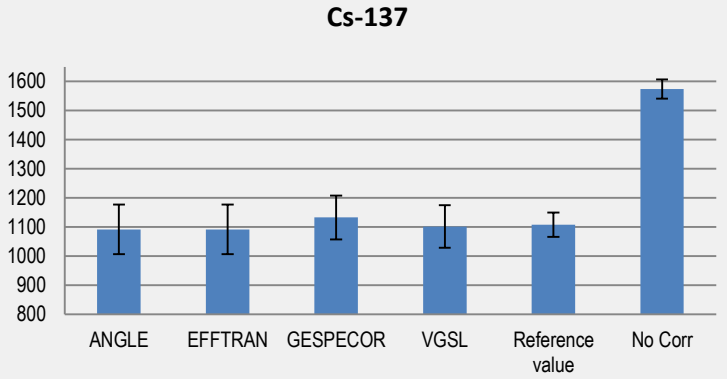
cont. 6. Density and matrix corrections

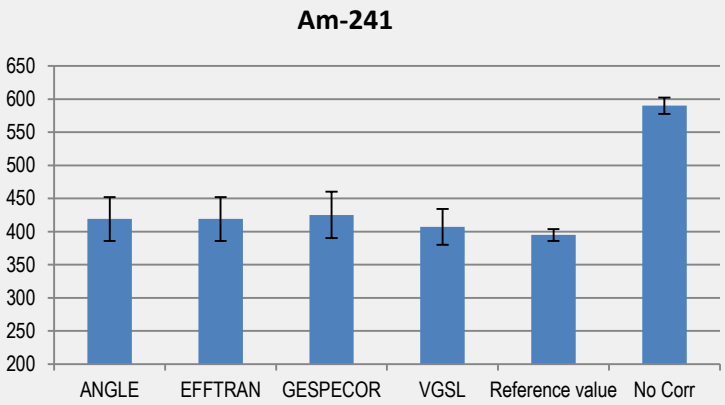
- Grass, density 0.33
- 60mL sample
- 60mL container

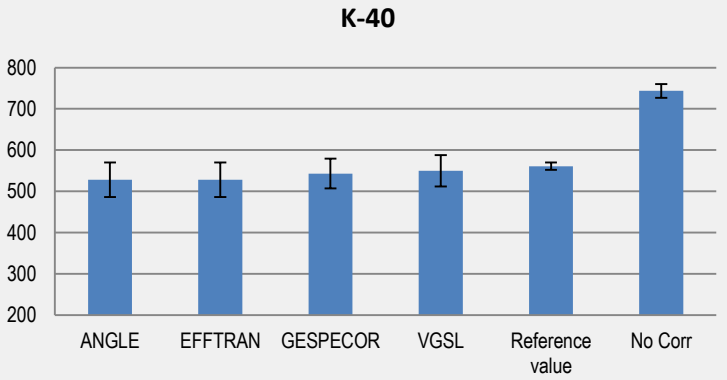


cont. 6. Density and matrix corrections

- Soil sample (IAEA 135)
- Density 0.98 g/cm^3
- 10mL sample
- 60mL container
- Unc. Volume correction 3.5%







Conclusions

End cap Calibration

- The chosen approach for establishing a coincidence free calibration was successful
- The coincidence free calibration enables us to do more accurate activity determinations in the high energy area (>661 keV)
- The established calibration works well as reference curve for the semi-empirical codes

cont. Conclusions

Volume and geometry corrections

- 60 mL (50% and 25% fill)
  - < 10% deviation from the reference value for almost all values
  - < 5% deviation from the reference value for all activities calculated with EFFTRAN
- 200mL
  - <10% deviation from the reference value for all calculation codes except ANGLE
- 5mL
  - <10% deviation from the reference value with EFFTRAN and VGSL
  - <15% deviation from the reference value with GESPECOR
  - >15% from the reference value with ANGLE

- For volume corrections the additional uncertainty is proposed to be 3.5%
- For geometry corrections the additional uncertainty is most likely larger.
- Acceptable results for GESPECOR and ANGLE under the given circumstances
- Less successful results with GESPECOR and ANGLE can most likely be explained by
  - Optimisation of detector parameters were performed with VGSL only
  - Less experience with GESPECOR and ANGLE

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cont. Conclusions

Calculation of correction factors with codes

- TCS corrections works well for all three calculation codes
- Corrections for geometries more closely resembling the calibration geometry are generally more successful
- The calculation codes succeeded relatively well even for more extremely deviating geometries
- Correction for density was not possible to validate with the available reference materials.

cont. Conclusions

General impressions from the use of the different calculation codes

- User friendly
- This study has helped us to gain better understanding and control over corrections for systematic effects over a larger energy range
- We have gained better understanding for the different calculation codes
- Important to know your detector system and the calculation code
- For laboratories that does not make corrections for systematic effects in gamma spectrometry, the use of a calculation code can be relatively simple to implement and able to deliver results ‘fit for purpose’

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Thank you

Any questions?