Gamma-Ray 2018,

hosted by Icelandic Radiation Safety Authority

Sensitivity of TCS correction factors to uncertainty in the total efficiency

Tim Vidmar

SCK.CEN, Belgian Nuclear Research Centre, Boeretang 200, Mol, Belgium

Tim.Vidmar@sckcen.be

Copyright notice

SCK•CEN
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSEL
Operational Office: Boeretang 200 – BE-2400 MOL

Coincidence summing corrections in a modern environmental gamma-ray spectrometry laboratory:

- TCS (true coincidence summing) correction factors are increasingly being calculated, rather than measured
- Made possible by increased computer speed, available software, Monte Carlo methods
- Saves time, money and effort
- Virtually unavoidable with samples of different sizes, compositions and densities and / or
- with many different radionuclides to consider

Uncertainty of the computed TCS correction factors has to be estimated:

- Part of the complete uncertainty budget
- Required by QA
- Not easy to establish

Estimation of the uncertainty of the TCS correction factors:

- Expert judgment
- Literature
- Inter-comparison exercises

Estimation of the uncertainty of the TCS correction factors:

- Summing out is the dominant process
- The decisive factor is the uncertainty of the total efficiency
- Decay scheme uncertainties smaller, computation relative
- Summing-in in generally less important

Systematic study:

- 300 radionuclides, 1400 gamma lines
- 2 detector types
- 4 sample types
- Assumed error in the total efficiency 10 – 20%
- Full-energy-peak efficiency usually known much more precisely

Systematic study:

- EFFTRAN code – quick computations
- Code first run with the original data
- Entire total efficiency curve then shifted upwards
    - Computation repeated

Detector parameters. All dimensions are given in millimetres (mm). The housing diameter is in all cases the same as the window diameter.

Parameter	**Detector A**	**Detector B**
Crystal material	Ge	Ge
Crystal diameter (including the side dead slayer)	60	60
Crystal length (including the top dead layer)	60	60
Dead layer thickness (top and side)	1	0
Hole diameter	10	10
Hole depth	40	40
Window diameter	80	80
Window thickness	1	1
Window material	Al	Al
Crystal-to-window distance	5	5
Housing length	80	80
Housing thickness	1	1
Housing material	Al	Al

Sample parameters. All dimensions are given in millimetres (mm).

Parameter	**Water**	**Point**	**Soil**	**Filter**
Sample diameter	90	-	60	80
Sample thickness	40	-	20	3
Sample material	Water	-	Dirt	Cellulose
Sample-to-window distance	0.0	1.0	0.0	0.0

Characteristics of various detector and sample materials. All densities are given in g/cm3.

Material	Density	Chemical formula
Ge	5.323	Ge
Al	2.70	Al
Water	1.0	H_2O
Dirt	1.4	SiO_2
Cellulose	0.3	$C_6H_{10}O_5$

Total efficiency uncertainty propagation – Co-60:

$$C = 1/(1-\varepsilon_{t2})$$

$$\Delta C = (dC/d\varepsilon_{t2})\Delta\varepsilon_{t2} = 1/(1-\varepsilon_{t2})^2\Delta\varepsilon_{t2} = C^2\Delta\varepsilon_{t2}$$

$$\frac{\Delta C}{C} = C\Delta\varepsilon_{t2} = (C\varepsilon_{t2})\frac{\Delta\varepsilon_{t2}}{\varepsilon_{t2}}$$

$$\varepsilon_{t2} = 0.1, \Delta\varepsilon_{t2}/\varepsilon_{t2} = 0.1 \xrightarrow{\text{yields}} \Delta C/C = 0.01$$

Total efficiency uncertainty propagation – Co-60:

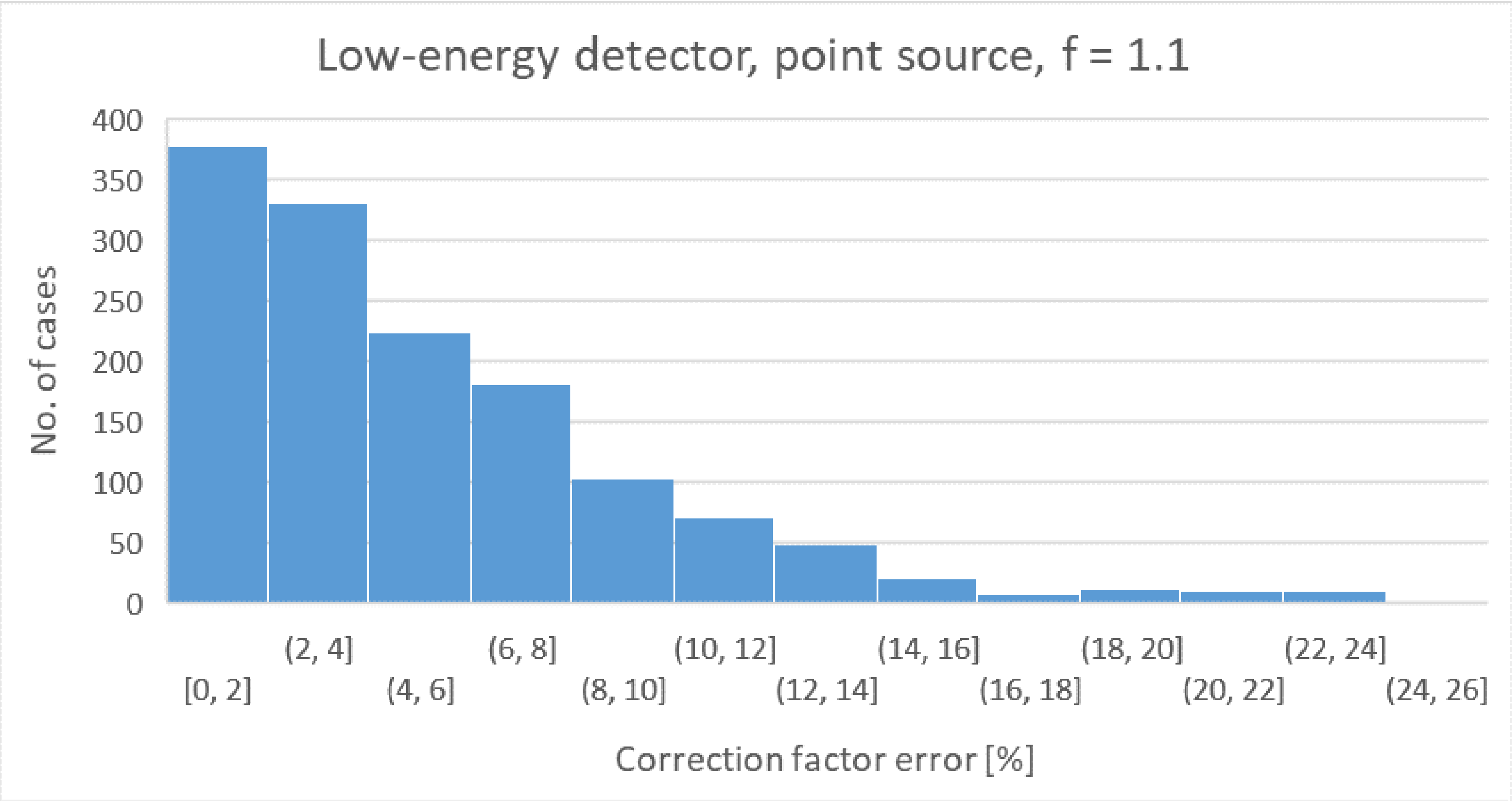
$$C = 1/(1-\varepsilon_{t2})$$

$$\Delta C = (dC/d\varepsilon_{t2})\Delta\varepsilon_{t2} = 1/(1-\varepsilon_{t2})^2\Delta\varepsilon_{t2} = C^2\Delta\varepsilon_{t2}$$

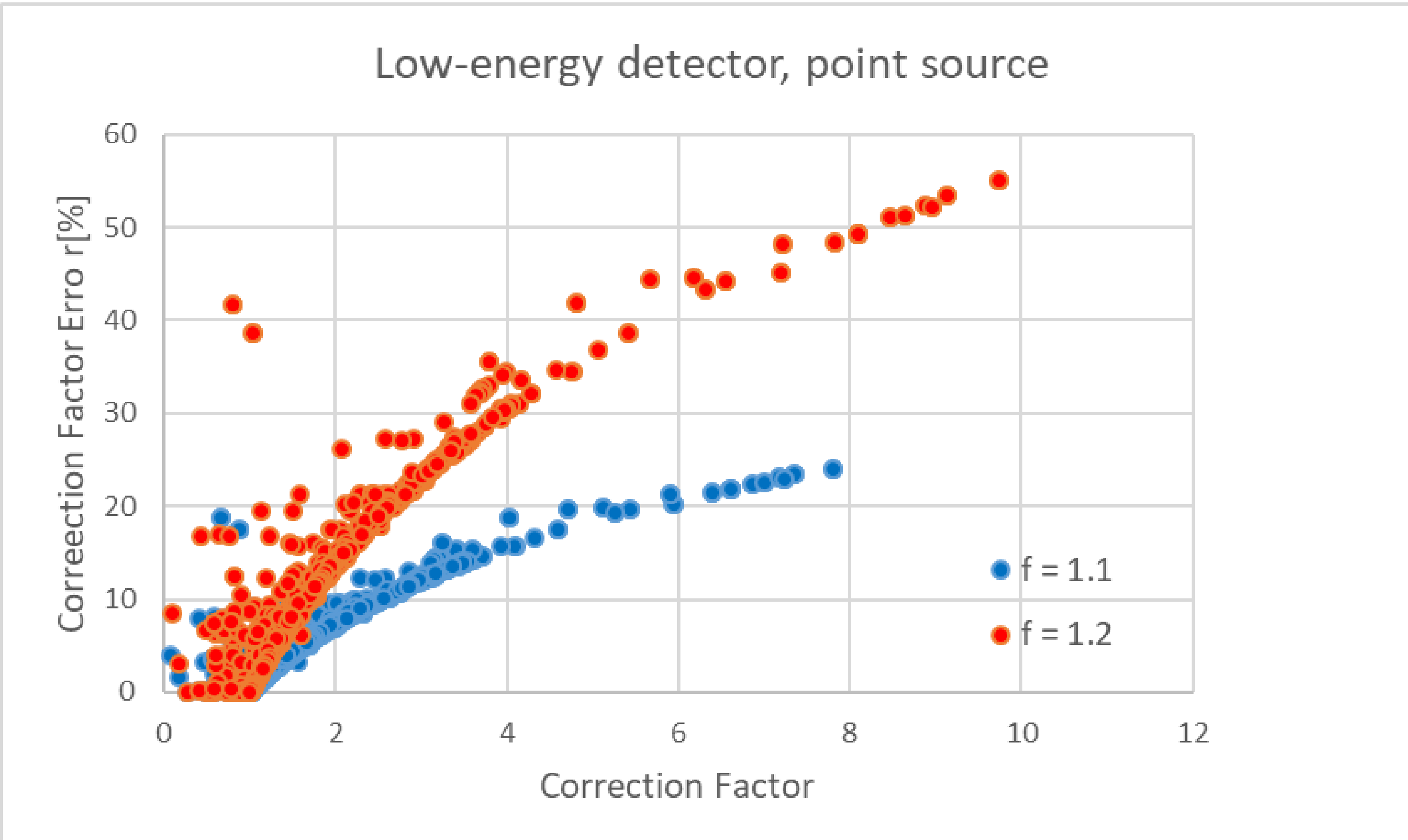
$$\frac{\Delta C}{C} = C\Delta\varepsilon_{t2} = (C\varepsilon_{t2})\frac{\Delta\varepsilon_{t2}}{\varepsilon_{t2}}$$

$$\varepsilon_{t2} = 0.1, \Delta\varepsilon_{t2}/\varepsilon_{t2} = 0.1 \xrightarrow{\text{yields}} \Delta C/C = 0.01$$

Results: Distribution of TCS uncertainty



Results: TCS uncertainty dependence on the TE error



Results: Average TCS correction factor uncertainties.

	Shift Factor 1.1		Shift Factor 1.2	
Detector/ Sample	High-energy	Low Energy	High-energy	Low Energy
Water		1.3		2.6
Soil		1.9		3.8
Filter		2.2		4.5
Point	5.0	3.3	10.7	6.9

Conclusions:

- (Preliminary) systematic study of computed TCS correction factor uncertainty carried out
- The average uncertainty can vary a lot, depending on the detector and sample type
- Proportionality to the magnitude of the correction factor itself and the error in the total efficiency
- Such an approach can be used to quantify the (average) TCS correction factor uncertainty encountered in a given lab